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THE SCIENTIFIC MONTHLY

JUNE, 1918

A GLANCE AT SOME FUNDAMENTAL ASPECTS OF MATHEMATICS

By Professor C. J. KEYSER

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IN a recent book Sir Oliver Lodge has said that "the mathematical ignorance of the average educated person has always been complete and shameless." To those who know how vast a body of human achievements the term mathematics has come to denote, to those who are aware of the immense development of the subject in modern times, and especially to such as understand and value its spiritual significance as manifest in its bearings upon the higher concerns of man, this indictment can not fail to seem a pretty terrible charge.

The charge is a double one: complete ignorance and shamelessness. The two counts, however, are not independent and this fact is a mitigating consideration. If the first count be correct, the second must be so too. For complete ignorance is complete innocence and innocence is never ashamed. Is the first count correct? The answer depends. For what does Sir Oliver mean by an "educated person"? He has not told us. He might, of course, have so defined the term that his statement would be true by definition. He might, for example, have said that by "educated" he meant what the world means by it. In that case the indictment would be just. For the world has never deemed incompleteness of mathematical ignorance to be essential to education. If, however, Mr. Lodge wishes us to understand that by "educated" he means *liberally* educated, then the indictment is unjust, provided one conceives liberal education as the late Lord Kelvin conceived it; for this great man used to tell his students that among the "essentials of a liberal education is a mastery of Newton's 'Principia' and Herschel's 'Astronomy.'" But are there not educators who would deny Kelvin's contention? Undoubtedly there are and

have been many of them. Such educators, for example, as Matthew Arnold, John Henry Newman and Thomas Huxley, widely divergent as are their outlooks upon the world, would yet unite in denying the contention impetuously or even with scorn.

It is evident that Mr. Lodge's deliverance is debatable. Certainly it is worthy of consideration. But who will consider it? May we expect its consideration by those whom it inculpates? If so, what should we expect the culprit to say? Well, he might speak as follows: I am an ordinary representative of the large class of average educated persons. You, Mr. Lodge, presumably represent the class of average mathematicians. You have said of me and my kind that our mathematical ignorance has always been complete and shameless. I in my turn desire to say of you and your kind that your average mathematician has always been completely and shamelessly indifferent in the matter of disclosing to his fellow men and women the cultural value of his science. Regarding our mathematical ignorance, which I regret to say is profound, though it is not quite complete nor entirely unashamed, I desire to say that it is not wholly due to the lack in us of mathematical faculty, but is due in large measure to the failure of mathematicians to show us that their science, over and above the appeal it makes to a class of specialists and technicians, is qualified to minister in any precious or important way to the spiritual needs which we have in common with all mankind.

Some such retort the average educated person may, I think, be conceived as making, not without justice, to Sir Oliver's allegation. In saying this I am far from intending to say that mathematicians have been wanting in devotion or patience or skill in presenting their science to multitudes of boys and girls and young men and women in its *technical* aspects. Nor do I mean to intimate that mathematicians may be rightly blamed for not making genuine mathematicians out of more than a very few of those they thus instruct, for every one knows that the genuine mathematician must be born before he can be bred. What I do mean is this: Among the countless host and endless variety of ideas that enter as components into the structure of mathematics there are a few concepts of so great generality and so great organizing power that they are superior to all the others in dignity and importance, serving as bases of the stately edifice or as its general framework or as central supporting pillars, like a tree-trunk to the tree or like a spinal column in the case of a vertebrate animal, giving the whole ideal architecture

its substance, its character, its coherency, and its everlasting stability. Now, for the full unfolding of the implicit content of these supreme ideas it is indeed necessary to employ all the curious symbolism and all the other intricate machinery that more than twenty centuries of mathematical ingenuity have been able to invent, for these supreme ideas are just the things of which mathematics is the science. But—and herein lies the justice of the foregoing supposed retort—the great ideas themselves are all of them near at hand, and it is possible to present them, as mathematicians never have presented them, in their more obvious aspects and ruder outlines intelligibly to their fellow men and women; it is possible so to present them that the layman may understand better than he has ever understood what are the things that make up the subject-matter of the mathematician's silent meditations; it is possible so to present them that the science which Plato called "divine," which Goethe called "an organ of the inner higher sense," which Novalis called "the life of the gods," and which Sylvester called "the Music of Reason," shall not seem to laymen to be remote from their interests nor detached from reality, but that it shall appear to them to deal as it does deal with the very essence of reality, penetrating life in all its dimensions.

What are those great concepts?

There is room here merely to glance at a few of them, to call their names and to indicate some of their more obvious aspects somewhat as a traveler in the foothills may note the peaks of a great mountain range above and beyond.

Among the major mathematical ideas there can be little doubt, I think, that the concept to which Mr. Bertrand Russell has given the name of propositional function is supreme. Every one is more or less familiar with the notion of the lawful dependence of one or more variable things upon other variable things, as the area of a rectangle upon the lengths of its sides, as the distance traveled upon the rate of going, as the volume of a gas upon temperature and pressure, as the prosperity of a throat specialist upon the moisture of the climate, as the attraction of material particles upon their distance asunder, as the rate of chemical change upon the amount or the mass of the substance involved, and so on and on without end. This notion of mutual dependence and reciprocal determination which is thus exemplified in every turn and feature of life and the world and whose scientific name of function was first pronounced, it is said, by Leibnitz, is indeed a very powerful concept; it has played a dominant rôle in modern mathematical analysis, giv-

ing at once name and character to certain great branches, as the theory of functions of the real variable and the theory of functions of the complex variable. Yet this Leibnitzian concept, powerful as it is, is far inferior to that denoted by the term propositional function, which embraces the former merely as an exceedingly important special case. What, then, are we to understand by this more comprehensive term?

The answer is that a propositional function is any statement containing one or more real variables, where by a real variable is meant a name or a symbol whose meaning, or value as we say, is not determined by the statement, but to which we can at will assign in any order we please one or more values or meanings, now one and now another. I fear that what I have just said is too general and too abstract to be quite intelligible. The idea can be made clear, however, by some simple examples, provided the reader will understand that the examples are related to the general concept in question as a burning match to a world-conflagration or as a few water drops to a boundless ocean. Let us denote real variables by such italicized symbols as x, y, z, w, etc. Then for concrete and familiar examples of what is meant by propositional function we may cite the following quite at random: x is a man; x is a lover of y; x is the specific gravity of y; x, y and z are the coordinates of a point on the sphere whose center has x', y', z' for coordinates and whose radius is w; and so on *ad infinitum*. How many variables may enter a propositional function? As many as we please. How many such functions are there? It is evident that their name is legion—the host of them is literally infinite in multitude. Even so, you may wish to say, the examples are not impressive. And you may naturally doubt whether the concept they serve to exemplify can be so gigantic and majestic after all. I repeat, however, that the idea is sovereign. In the great and growing system of mathematical ideas, the concept of propositional function is indeed "like Jupiter among the Roman gods, first without a second." Its majesty, its power, its subtlety, the immeasurable range and depth of its significance can not be perceived and felt at once, but only more and more with days and months and years of reflection.

Let us reflect a little upon it. Every one knows that nothing can be more important than propositions. Why are propositions so important? Because truth and falsehood are so important, and propositions are just those living things in which truth and falsehood reside or to which they attach—a proposition is whatever is true or is false. Well, we are going to see

presently that propositional functions are related to propositions as matrices are related to the things they mould. Again, no one can fail to recognize the importance of the idea of a class. Without this idea life would no doubt be possible but human life would not, not even for a day. So important is it that in all philosophic ages the concept of class has been held, not quite justly, to be supreme, and for more than two thousand years logic, the science of thought as thought, has been the doctrine of classes. What of it? As in the case of propositions, so here too: We shall see that it is from propositional functions that what we call classes derive their definitions and the determination of their content. And what shall we say of relations? Who does not know that our universe presents itself under scrutiny as an infinite plexus of relations? Who does not know that what we call things—whether they be objects of sense like the moon or objects of pure thought like the orbit of the moon—are but nodes or ganglia where relations meet and pass like a mesh of invisible wires uniting the many into one? "Being," says Lotze, "consists in relations." And it is not things themselves, says Henri Poincaré, that science can reach, as the naïve dogmatists think, but only the relations of things. "Outside of these relations there is no knowable reality." What, then, shall we think of propositional functions if these turn out, as in fact they do turn out, to be the forms in which all relations, whether of things or of ideas, are moulded and defined?

To see the connection of propositional functions with propositions it will suffice to consider some familiar propositional function, the simpler the better. Consider the homely function; x is a man. Observe that this function, though it has the form of a proposition, is not a proposition; for a proposition is true or is false, but the statement—x is a man—can be neither true nor false so long as x has not received an admissible meaning or value (such as Socrates, say), but when such a value has been assigned we no longer have a function, but have a proposition; namely, Socrates is a man. Thus we see how propositions, which are constant and which may be called values of the function, are derivable from the function, which in its turn is not a constant, but is a variable owing its variability to the presence in it of one or more unassigned terms or variables such as x, y, etc. Is this so easy as to be uninteresting and unimpressive? If so, that is no reason for being disheartened, for there are difficulties enough near at hand. Let us notice one of them. I have spoken of "admissible" values of x.

What is such a value? It is one that, when put for x in the function, yields a significant statement, a statement, that is, that makes sense, as we say. In other words, an admissible value of x is one that converts the function into a proposition, into something that is true or else false and not into mere nonsense. But our universe contains an infinitude of constant terms. Are all of these admissible values of x? No; the term John Smith is admissible, and so is the name Fido (the designation of my dog) for the statement—Fido is a man—is significant, it is a proposition, although it is false. Indeed, if it were not a proposition it could not be false, for, as already pointed out, propositions are the only things that can be false or true. Now men constitute a *class*. Is this class an admissible value of x? Evidently it is not, for the class is logically subsequent to the individuals composing it, and so it can not, without logical contradiction or nonsense, be said to be one of its own members. Accordingly, the statement—the class of men is a man—is neither true nor false; it is, rightly understood, just sheer nonsense. It is easy thus to see that our simple and homely propositional function, x is a man, cleaves the universe of terms or values into two infinite parts; one part being composed of inadmissibles and the other of admissibles. Is the line of cleavage always sharply defined? No; it may be doubtful whether a given term is or is not admissible, for we may ask, for example, whether the sweetness of sugar or the glory of renown is, in case of the function under consideration, an admissible value of x. There is here an open and inviting field for scientific research, the problem being to determine the best possible criteria for deciding, in case of any given propositional function, what terms or values are admissible and what ones are not. The situation may be likened to that of physical organisms, for there are plants and there are animals, but in the case of some living organisms there is at present no means of deciding to which division of the kingdom they belong. It is plain, too, that just as a propositional function containing a single variable parts the universe of terms into two infinite divisions of terms, so a function of *two* variables sunders the universe of *couples* of terms into two infinite divisions of couples; and so on and on for the case of three or of four or of n variables.

Again confining our attention to some concrete propositional function of a single variable, let us, for the sake of convenience, denote it by the symbol $F(x)$. Then, if a and b denote admissible values of x, $F(a)$ will be a proposition and so will $F(b)$.

It may happen that one of these will be true and the other one false. Such will be the case if, for example, $F(x)$ means "x was a great Italian poet" and if a denote Dante and b denote Shakespeare. Thus it appears not only that every propositional function of a single variable divides the universe of terms, as we have seen, into two grand divisions, but also—and this is exceedingly important—that the grand division composed of admissible values is at the same time separated by the function into two classes: namely, the class of values that yield true propositions and the class of those that yield false ones. Now the former of these classes, because of its relation to truth, enjoys the distinction of being regarded as *the* class determined by the given function. Is there a function that in this sense determines the other class? Yes; the other class is determined by the negative of the given function. Now a value of the variable that converts a function into a true proposition is said to *satisfy* the function. Accordingly a class consists of all and only the terms or values that satisfy some propositional function. To each function there thus corresponds a determinate class, one and but one. Is the converse true? A class being given, is it true that there is one and but one function that determines the class? Far from it. Given a class, there are, in general, many different functions, each of which suffices to determine it. Thus "x is a prime number" and "x is not divisible by any number except 1 and x" are two functions determining the same class, having, as we say, the same extension, the difference of the functions being what is called intensional difference. And this brings us to the weighty notion of *equivalence* among functions, two propositional functions being said to be equivalent when and only when they determine the same class. It is a very important and often a very difficult problem, when a function is given, to determine whether certain other functions are or are not equivalent to it. Is there a universal class? There is. Such a class may be defined by the function: x is identical with itself, or with x. But it must not be inferred that a universal class includes all things, for such an inference would lead quickly to logical contradiction, or nonsense. A class that included all things would have to include itself and such inclusion is logically impossible, it is nonsensical. There are classes of individuals, classes of classes, classes of classes of classes, and so on upward forever; so that classes and their corresponding functions constitute a summitless hierarchy of types or ranks—a subtle matter that can not be further pursued here, but which has to be faced and which

has been faced bravely and with much profit to philosophy and science by Messrs. Whitehead and Russell in their magnificent "Principia Mathematica." Suffice it to say here that the notion of identity and that of universal class must be defined independently for each rank in the hierarchy or else extended from rank to rank by means of some more or less plausible assumption. To the universal class of any given rank there corresponds its negative: namely, the class determined by a function not satisfied by any value of the variable. Despite the fact of its containing no members, this so-called empty or null class is said to exist for the reason that there exists a propositional function determining it. And this strange class is very important because it lies at the basis of that curious integer which is known as *zero* and which is so indispensable to science and to the conduct of civilized life.

I fancy that the non-mathematical reader may wish to say: "What has all this to do with mathematics? I have always supposed that mathematics is the science that deals with number and space, and I quite fail to see any very obvious or close or significant connection between propositional functions on the one hand and the various kinds of number and of space configurations on the other." Very well, let us pause here a moment to exhibit such a connection. You doubtless think nothing can be more familiar than the numbers 1, 2, 3, etc., with which we count. What is it that we humans mean by the number 3 or the number 5, for example? There are probably not more than 2,000 people in the world who can answer that question. In answering it, I shall be relating a piece of the very latest scientific news. Consider the propositional functions: x is a finger of my right hand; y is a finger of my left hand. Each of these functions determines a class. The two classes, c and c', are said to be *equivalent* because we can pair the things of the one class with those of the other in a thing-to-thing way. By such a pairing we are said to *transform* each class into the other, and so we note in passing that the important mathematical term transformation does not mean what it means in general literature, for in general literature it involves the idea of transmutation; but classes that are mathematically transformed are merely associated and are not changed or transmuted into something else. Mathematical transformation is purely psychical, it is merely a lawful way of transferring our attention from a given thing to a definitely associated thing. To return from this digression: are there any other classes that are each equivalent to c and hence to c'? Obviously there are many of

them, as the class c'' of letters in the word *write*, the class c''' of toes of a normal human foot, and so on and on. It is now essential to note carefully that there is a class C composed of all those equivalent classes. Observe that the members of C are not fingers, toes, letters, etc., but are classes c, c', etc. Do you know what C is called? In English it is called *Five* and is everywhere denoted by the symbol 5. Thus the number five is simply a certain class of certain equivalent classes, and the name five and the symbol 5 are simply the name and the symbol of that class. Exactly the like is true of all other integers. Does the fact seem strange? Well, science can not agree to discover nothing but what is familiar. Have we answered the question: what is an integer? No, we have merely indicated how to tell precisely what is meant by the number of any *given* class. To tell what is meant by the general phrase, an integer, we must go higher, we must form a more tenuous concept, we must say that the phrase stands for the class Σ of all the classes formable, like C, of classes of things. Here we gain an insight into the reason why the doctrine of number makes such severe demands upon intellection. For observe that a finger is indeed a sensible thing, but that the class c of fingers is not sensible, but is a pure concept. The class C is then a concept of concepts, and the class Σ is a concept of concepts of concepts; and accordingly the meaning of the phrase, an integer, is thrice removed from the domain of sense.

I have now shown how propositional functions are connected with the most familiar of mathematical things; namely, the integers, or count numbers of the shopkeeper. But there are many other sorts of number, as the rational fractions; as the real numbers including such as e, π, $\sqrt{2}$, etc.; as the complex numbers, which involve an even root of some negative real number; and so on. And you may wish to ask: Are all these and are all the configurations studied in geometry connected with propositional functions? They are. To show it, however, it is necessary to show, as I have promised to show, that the notion of propositional function is the source of the great concept of relations.

And that is not hard to do. Let $F(x,y)$ denote any one whatever of the propositional functions that contain two variables x and y. To fix our ideas, as French writers say, let us take the function: x is the lover of y. Any such function determines a class of *couples*, namely, the ensemble of ordered pairs of values of x and y that convert the function into a true proposition. If a loves b, then a and b, taken in the order named,

are together one of the couples. Such a couple may be called an *element* of the *relation determined by the function.* Now just what, you may wish to ask, is the relation so determined? The answer is: the relation is the ensemble of all such elements or couples. Thence it appears that in mathematics a relation is regarded as consisting of its *extension* as distinguished from its *intension.* Thus the two functions, "x is greater than y," and "u is neither equal to nor less than v," though they differ in respect to intension, are said to determine the same relation because the two classes of couples determined by them are identical. Every propositional function of two or more variables determines a relation, and the relation is called dyadic or triadic or n-cornered, according as it is determined by a function of 2 or of 3 or of n variables. It is at once evident how infinitely rich and complicate the world of relations is. Let us for the present speak only of dyadic relations. If R denote such a relation, we may say that x has the relation to y by writing xRy. At once we see that dyadic relations have direction or sense, for if aRb, it is generally, though not always, false to say bRa. The things that can stand before a given relation constitute its *domain;* those that can stand after it, its *co-domain;* the domain and co-domain, which may or may not have things in common, together constitute the relation's *field.* Obviously relations present themselves under certain striking types. Thus there are *symmetric* relations, equality for example or diversity, such that if aRb, then also bRa; there are *asymmetric* relations, father or greater, for example, such that, if aRb, then never bRa; there are *non-symmetric* relations, friend, for example, or brother, such that, if aRb, then sometimes but not always bRa; there are *transitive* relations, less for example or identity, such that, if aRb, and bRc, then aRc; and there are intransitive relations, non-transitive relations, one-to-many relations, many-to-one relations, one-to-one relations, like that of husband or that of wife in well-regulated communities, many-to-many relations, and numerous other distinctions.

And now a word regarding applications to familiar mathematical things. A rational fraction is simply a kind of dyadic relation among integers. Thus, the fraction *two thirds* is the relation—that is, the class of couples (a, b)—determined by the propositional function, $3x=2y$. Of real numbers as distinguished from rational numbers I shall speak presently in connection with the concept of *Limit.* As to geometry, any one a little acquainted with the analytical method discovered by Descartes and Fermat can readily see that any space config-

uration whatever is a relation. For, to pass abruptly to 3-cornered relations, if x, y, and z be the coordinates of a point—that is, if they be its distances from three chosen planes of reference—then any propositional function, such as $2x^2 + 4y = 9z + 3$, determines a relation among points and this relation is called a surface.

In support of my statement that the notion of propositional function is sovereign among mathematical ideas, I have said enough in this sketch to show that this omnipresent notion embraces the great concepts of proposition, class, and relation like an infinite envelope inwrapping them completely and touching them, so to speak, at every point. I must now hasten on to other pillar-ideas without, however, passing beyond the range of "Jupiter," for that can not be done.

A masterful idea that owes its precision and its great fame to mathematics but which, as we shall see, has everywhere penetrated, under a thinner or thicker disguise, the history of thought and aspiration, is the notion of limit. May I remind you by an example what the notion means? Suppose we are operating in the field of the *rational* numbers. Consider the series or sequence of all the rationals such that the *square* of each is less than, say, the sacred number 7. Then we say that the sequence has a *limit,* which we call the square root of 7 and denote by $\sqrt{7}$. But this thing, this limit, is not a rational number; it is something outside the field of rationals; it is merely indicated and approached by the rational sequence. In relation to our field of operation, this limit is then not an actual thing, but is purely ideal and the process of approaching it along the sequence is, as you see, a process of idealization. It is thus evident that the notion of limit and the process of limits, which lie at the basis of the Newtonian and Leibnitzian calculus and which are indispensable to mathematical computation and generalization (as leading, for example, to the concept of such irrational numbers as $\sqrt{7}$), it is evident, I say, that this concept and this process are but mathematicized forms of those ideals and that process of idealization which in other fields of interest have given man his dreams of perfection, whether in ethics or in religion, or in art, or in governance, or in knowledge. Every manner of perfection, every genuine ideal, every source of supernal light upon our human pathways, is indeed some great unmathematicized limit, unattainable indeed, yet indicated and pursued by familiar sequences of experience in our common life.

In our hasting excursion among the great mathematical

ideas, we must not fail to glance at the concept called a system of postulates. It is a system composed of a few so-called axioms or assumptions or propositions called primitive because they are taken for granted, it being impossible to prove everything. The purpose or office of such a system is to serve as a foundation for a doctrine all of whose propositions, except the postulates themselves, are to be logically demonstrated. If a postulate system is to be an ideal one it must be such that the postulates are compatible—that is, not mutually contradictory—and they must be independent in the sense that none of them can be logically derived from the rest. In the course of more than two thousand years, and especially in our own day, numerous such systems, or mathematical branch-foundations, have been discovered. A famous one of these is found in the late Professor Hilbert's "Foundations of Geometry." In every postulate system the postulates are statements about certain terms, or elements as they are often called. These terms are *not defined* beyond the requirement that they must satisfy the postulates or, in other words, that they must be things about which the postulates make true statements. In Hilbert's system, for example, the undefined terms are point, line, and plane. Since the terms are undefined we may as well replace them in the postulates by the variables x, y and z and then it appears on the very face of the postulates, since they now talk about the variables, x, y, and z, that they are not propositions, but are propositional functions. And hence it appears that the so-called doctrine erected upon them is really not a doctrine, for a doctrine must be true or false, consisting of propositions, but is really a *doctrinal function* depending upon the propositional functions at its base. By giving these variables admissible meanings, or values, we get doctrines from the doctrinal function just as propositions are obtained from propositional functions. One of the impressive facts recently discovered in this field is that from a given doctrinal function we can thus derive an infinitude of doctrines, some of them true, some of them false. Inasmuch as these have the same foundation, they are all of them of the same form; they are *isomorphic*, as we say; they are logically *one*, but psychologically they are *infinitely many*. Who can tell the disadvantages that would attach to living in a world, if there were such a world, where every doctrine required a foundation of its own?

Before quitting the subject of postulate systems I desire to mention two considerations, one of them touching the humanity of mathematics, the other indicating one of its fundamental

bearings on philosophy. The first consideration is that in seeking a postulate system to serve as the support of a mathematical branch, the mathematician is engaged in the very human work of searching for principles, for beginnings that will guide, and his activity, though it is distinguished by its precision and ideality, is, in point of *kind,* not different from that common quest of man in all ages for fundamental truths which has eventuated, not merely in such scientific things as the principles of Newtonian mechanics, for example, but in decalogues, in creeds, in political constitutions, and in principles of jurisprudence. The other consideration is that by their postulational research, mathematicians have conclusively demonstrated that the now age-long attempt of philosophy to derive the universe from a principle or from a consistent set of principles can never be successful, not because man is lacking in wisdom but because the problem admits of no solution. How is this shown? It is shown by this: Geometricians have discovered three geometries, one of them called Euclidean because, like Euclid, it postulates that in a plane there is through a given point one and but one line parallel to a given line; one of them called Lobachevskian because, like Lobachevsky, it postulates more than one such parallel; and one of them called Riemannian because Riemann postulated that there should be no such parallels at all. Now each of these three classic geometries is internally consistent and is, therefore, indestructible. But the geometries contradict one another. Accordingly we have in our universe these three eternal but mutually incompatible doctrines. If a consistent theory of the universe could be constructed on the basis of a single set of compatible postulates, then the geometries in question, being a part of the universe, would have to be derived with all the rest of it as harmonious affairs; but this can not happen, since neither men nor gods can render concordant two things that contradict each other categorically. To think otherwise would be to abolish the very notion of logical harmony. Herewith, then, is established by mathematics an eternal limit to the possible advancement of philosophical speculation.

Space fails me to deal suitably with such momentous concepts as those of infinity, group, hyperspace, and invariant. As to the first of these I may perhaps be permitted to refer an interested reader to my book, "The New Infinite and the Old Theology," where I have presented, in the language current among educated people, the mathematical concept of infinity together with its bearings upon some problems of rational

theology. The concept of group, which entered mathematics about a century ago and which, besides giving rise to an extensive doctrine of its own, has come to serve more and more for the characterization and classification of other mathematical branches, would require a separate essay to present it adequately to laymen along with its bearings upon general thought, ancient and modern. The same must be said of hyperspace.

As to the notion of invariance, it has played so great a rôle, not only in mathematics, but in every cardinal field of human interest, that I can not close without giving at least a little sketch of its nature and significance. What is an invariant? Broadly speaking, it is anything, simple or complex, that remains unaltered when other things connected with it suffer change. The mathematical theory of invariance is about as old as our American independence. Its beginning was like a mustard seed. The seed was an observation by Lagrange that the discriminant, $b^2 - ac$, of the quadratic equation, $ax^2 + 2bxy + cy^2 = 0$, is the same for all the countless equations that can be obtained from the given one by replacing the x in it by $x + \lambda y$, λ being allowed to take any and all numerical values. The mentioned replacement is a very simple example of what is known in mathematics as a transformation, of which I spoke briefly above. Thus what Lagrange noticed was the fact that the above-mentioned discriminant remains invariant under an endless number of transformations. If the reader will take the trouble to reflect for a moment upon the fact that an equation may contain any givén number whatever of variables and upon the further fact that, the number of variables being assigned, the equation involving them can have any degree whatever, and if he will then reflect that the number of coefficients increases very rapidly with the number of variables in the equation and with its degree, he can not fail to glimpse the magnitude of the problem which consists in searching out *all* those combinations of the coefficients or of the coefficients and the variables together that remain unchanged when the equations are transformed by replacing in them, not merely one of the variables, as in the example of Lagrange, but each of them by an expression containing them all. That is the magnificent enterprise to which, as a result of Lagrange's tiny observation, mathematicians engaged for some generations, first Gauss, then George Boole, then Arthur Cayley and James Joseph Sylvester and then a small army of master-workmen both British and Continental. The event is a stately doctrine variously styled

the theory of invariants and covariants, the theory of quantics, as Cayley was wont to name it, and the calculus of forms, as it was more poetically conceived by Sylvester. The notion of invariant has been extended far beyond the range of algebra in which it originated, into all branches not only of mathematics, but of natural science. A little reflection will suffice to show that nothing can be closer to the heart of man than this seemingly cold and arid mathematical concernment with the doctrine of invariant forms. For it is obviously only the mathematical aspect of man's quest, in all times and places of our fluctuant world, for abiding reality and which in art has given us the doctrine of eternal archetypes of beauty, in jurisprudence the ancient conception of *lex naturæ*, in science the idea of indestructible atoms and of invariant natural order or law, and in religion and theology such dreams as an immutable God and an immortality for human souls.

Finally a word respecting the bearings of mathematics upon ethics. No one can contemplate the ideal cosmos disclosed in mathematics, no one can realize how indissolubly ideas there are interlocked, no one can perceive that there consequences follow from chosen beginnings with a fatality against which not even God, said Plato, can contend, no one, I say, can face such aspects of our world without having his ethical sense touched by a sobering awe.

THE PSYCHOLOGY OF SOCIAL RECONSTRUCTION

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I

FOR the past three years there has issued from the English and American press a flood of books and articles on the subject of social reconstruction after the war. The writers differ widely as to the form that our social and political institutions will take, but there is almost complete agreement as to the goal to be attained. In these new writings one hears little about our once boasted "modern civilization," which, based as it was upon our peace societies and our arbitration treaties and our low percentage of illiteracy and our "freedom" of the slaves and our scientific discoveries and our mechanical inventions, is tacitly admitted to have been more or less of a failure. Instead, we hear now of a new social order, a new social mind, of socialism, of internationalism, of world peace and social justice. Nor is this new social order at all hazy in the minds of these writers. On the contrary, it is quite clear and definite. It involves certain definite social and political changes, such as *the future prevention of war, the more complete democratization of governments, the more complete socialization of the world, the harmonization of capital and labor, the greater equalization of wealth and opportunity, the complete emancipation of woman both politically and industrially, the suppression of alcohol, the greater control of disease and the lessening of crime.* This is the program, the goal towards which, in the thought of the day, society must move. And it is not merely the paper program of idealists: it is the actual working platform of a great number of social movements of intense vitality and life, of nationalists and internationalists, of social democrats and syndicalists and of a dozen different types of socialists. And even this does not indicate the strength of the movement. It is in the air. It is in the spirit of the age. It is in the unquestioned drift of events. So unbounded is our faith in the supreme value of this program, that to attain it we

believe that the price even of this awful war is not too great to pay. Even in the untoward event of the victory of the Central Powers, this social program will, as many believe, soon be attained because of the powerful social forces working beneath the surface in Germany and Austria and even in Turkey.

Neither is this program to be criticized on the ground that it is utopian. Too many Utopias have been realized in this rapidly moving age to borrow any trouble on that account.

But it would be interesting to ask how this social program strikes the psychologist. Probably every thinking man is enough of a psychologist to have observed that it is to be realized not by making over the human mind, but by making over our political and social institutions and by the passing of new laws. But, it will probably be added, no one could possibly object to finding himself in happier circumstances and human nature will quickly adjust itself to a social situation which is clearly so much better than our present one. Let us, however, examine this psychological aspect of the question a little more in detail.

II

We observe, first, that the method by which this picture of the new social state has been gained is the simplest in the world. It consists merely in enumerating the "evils" in our present social system and then outlining a plan in which these evils will be absent, a method much in vogue among all the utopianists from Plato to Mr. H. G. Wells. Poverty, for instance, is an evil. Since, now, there is plenty of wealth for all, let it be more equally distributed. Clashes between labor and capital are evil; they are to be prevented. Alcohol is an evil; let its use be prohibited. Disease is an evil; science will show us how to avoid it. Inequality is an evil; let women be given an equal place with men and let all men and all women be afforded an equal opportunity to gain their several ends. War is an evil; let there be some international machinery for the enforcement of peace. Autocracy is an evil; let the people rule everywhere. Waste is an evil; let there be conservation of all natural resources.

To abolish those evils is considered a kind of ultimate goal; like the marriage of the hero and heroine in the story, and "they lived happily ever after" is the invariable assumption in both cases. But when we awake from our castle-building, we realize that the hero and heroine do not always live happily ever after; and it is equally certain that the people of the world

may not live happily and contentedly in a social state characterized merely by the absence of evils.

The gist of the matter is simply this: We are living in an economic and social age and our minds are obsessed by economic, social and political ideas. When we turn to the subject of social reconstruction, we take into account only economic, social and political relations and, in spite of many warnings to the contrary, we fail to study the character of the units of which society is composed. In other words we disregard the vital and all-important psychological factor. Our theoretical social structures may, therefore, be just air-castles, in which actual human beings could not live. Our social reconstruction schemes may be of little value until they have been revised in the light of the teachings of psychology, history and anthropology. This is so obvious that it is hard to understand how the psychological and historical factors could be so neglected in these studies.

It is much too readily assumed that human beings will adapt themselves to the new social order because this order is ideally better. It may be better only for ideal beings, not for actual human beings. If this new order is actually better, and it certainly seems so, perhaps man can adapt himself to it in time. But there is no ground for the belief that the human mind is going to change much in the next thousand years, as it has not changed much in the past thousand.

Just here lies the whole difficulty. We happen to be living in a time of very rapid social and economic changes, while the physical and mental constitution of man has changed but little. The picture of the man of the Old Stone Age, as presented, for instance, by Professor Osborn in his recent book, reveals a tall, straight and fine-looking being, with a brow like that of a modern Englishman, and a cranial capacity somewhat in excess of the average European of to-day. Animal and human species are mutable, but this does not happen to be an age in which such mutations are rapid, while it does happen to be an age of dizzy and bewildering changes in our economic, social and industrial environment. Since the days of Aristides and Themistocles, the economic and social order has been completely transformed, while the human unit has changed but little, in respect either to his mental ability or to his fundamental instincts and interests. The changes that have actually taken place in man's nature are superficial, relating for the most part to his inventive powers and his altruistic emotions.

The surface of the earth happened to be underlaid with

iron, coal and petroleum, and man happened to discover them, and devise ways of using them, and they have suddenly made for him a totally new environment. Not only have they changed his environment, but they have produced disharmonies in his nature by compelling him to live under new conditions, for which evolution had not adapted him. For instance, the use of gasoline, steam and electricity has solved the problem of transportation without the healthful exercise of walking and carrying burdens. Electricity has enabled man to work and play at night, when formerly he had been sleeping. The construction of airtight, steam-heated dwellings has lulled him into comfort, while inducing new diseases. Coincidently, the discovery of alcohol has provided an artificial, but damaging quietus for the disharmonies caused by his new manner of life and his new efforts at thought. Finally, certain discoveries in hygiene have lengthened life and decreased infant mortality so considerably that, despite the decreasing birth rate and despite the extensive emigration to the newly discovered Americas, the population of Europe has increased from 110,000,000 in 1780 to 325,000,000 in 1911, a situation which from the standpoint of sustenance is beginning to create grave difficulties.

The other change in human nature is the sudden enlargement of the altruistic sentiments. These, originally developed because of their survival value in collective life, have for religious and incidental reasons been so magnified as to effect a change in society quite out of proportion to the actual changes in the human mind, adding a superficial grace, refinement and culture for which the human unit is not prepared.

III

The result of all these circumstances is that man in modern society finds himself in a position somewhat like that of the proverbial bull in the china shop. For a few minutes he seems to contemplate these objects of art with quite an esthetic interest, until he begins to move, when the destruction begins. The economic and social world in which man lived before the war, with its accumulated wealth, its culture, its refinement and its dangerous ease, was a china shop in which for a time he lived quite placidly, his real nature concealed under a veneer of civilization, till suddenly a very slight movement took place, the murder of an archduke somewhere, when instantly confusion reigned and the awful destruction began. It was man's

original nature asserting itself, his primitive instincts finding expression, and since we may be certain that they will continue to find expression for hundreds of years, it will be well to build our house of civilization to fit the man who is to live in it.

Certainly this does not mean that we are to make no efforts to eliminate war from human society. It means only that it is idle to construct artificial social schemes which are thought to be so planned that war cannot take place. It serves only as an illustration of the fact that our current ideas of social reconstruction present views of society so far removed from the actual instincts and interests of men that there is not the remotest chance that they can be realized. They do not provide for man's instinctive needs; they provide only for the elimination of evils. It is not even sure that they offer higher social values, since they center so persistently about the ideas of wealth, equality, peace, comfort and ease. Whether peace is better than war depends upon what the peaceful people are thinking and doing. If they are thinking nothing and doing wrong, war might be better.

To the social reconstructionist, the problem is delightfully simple. To the psychologist, it is frightfully complex. To the former, all we need to do is to eliminate war, poverty, intemperance, inequality, conflicts between labor and capital and other such evils, and the social problem will be solved. To the psychologist and student of history such a plan seems fraught with perplexing difficulties. When the frightful waste of war is stopped and the waste of labor strife, and the waste of intemperance, and the waste of disease, and the waste of child labor, and the waste of bad agriculture and bad forestry and badly managed industries, and when science and the mechanic arts have still further advanced man's dominion over nature, wealth will go on increasing faster even than before the war; and, if history and psychology teach anything, it is that mankind will not prosper under such a régime of wealth, even if it is equitably distributed. It has been said that the present war was due to the phenomenal increase of national wealth without a corresponding increase of morality. It is possible that a still further increase of wealth with its associated greed, its dangerous ease and its neglected discipline, might be a more fatal evil than any we are trying to escape.

It is true that man longs for wealth and comforts and luxuries. He even longs for peace and quiet and regular work, and in his quest for these things he will undergo any hardship

or deprivation. Hence, it is naïvely assumed that a society which shall provide him with these things will be an ideal society, forgetting that a good society will be one in which men can *live*, and that *life* consists not in the enjoyment of peace and wealth and comforts and luxuries, but in the longing for them and the struggle, pursuit and capture of them. The good things of the world must be won afresh every day.

But even this conception of life is narrow and academic. The real man, revealed to us by the study of psychology and of history, is wholly different from the man for whom the social Utopias are constructed, who is to live presumably in the enjoyment of regular work, plentiful food and clothing, a comfortable home, and social stability and peace. The real man acts from impulse rather than from reason and his primal impulse is to dominate. It is gain and glory that he wants more than bread and clothing. It is a career that he desires more than peace and safety. It is adventure that he craves more than work.

It is instructive to look back upon the history of the development of man in society. He is not by nature a worker, but an exploiter. Sustenance he must have, but it has always been easier to gain it by plunder than by work, and so, as far back as we may go in history, as at the present day, social group has fought against social group, one bent on robbery, the other on self-defense, and within the group, when unrestrained by the stern hand of the law, individual has preyed upon individual, master upon slave, and class upon class. When the life and safety of the group as a whole have been threatened by some rival group, then so much of law and order has prevailed within the group as was necessary for social integration, because only by social solidarity within the group could the group itself be saved.

It is not quite accurate to say that men love to fight. In time of war they long passionately for peace. But they love to dominate, and fighting is incidental. The military impulses lie very near the surface and their roots extend deep. If human progress is to be illustrated by a figure, it is not the figure of a man climbing a ladder, but of one elbowing his way up in a crowd. Men aspire always to something different and better. They love to gamble, to take a chance, to risk something and gain or lose. It is contrary to deep-seated human racial habits to work steadily and monotonously.

The conquest of a great and new country like America will

keep a people busy and contented for a century. When it is conquered, it is assumed that they will rest and enjoy it; but really that is when unrest begins. In the last years the world has grown rich and prosperous; but unrest has increased—unrest in America, unrest in England, unrest in Russia, unrest in Germany. In the past two years in America work has been plentiful and the times prosperous; but murders and bank robberies show no signs of abating. The American frontier, so long as it existed, was the best peacemaker for our nation. It has now been reached and conquered; and unrest will increase. The world's frontier has also been reached. Africa and the Pacific islands have been occupied and the world is getting restless.

How different the reality may be from the vision of the social idealists. In rich and fertile America we look forward to a land teeming with happy and contented citizens, free from war, free from foreign oppression, free from autocracy within, free from grinding poverty, free from class oppression, free from decimating disease, free from vice and intemperance. The nearest approach to this elysium which history has seen was in Germany before the war. Here was a land of beautiful cities, well governed and orderly; a great people, well fed, well clothed, well housed, well educated, well behaved with a fruitful agriculture, busy shops, successful industries and a vast and profitable commerce—yet this same Germany broke bounds and went out to conquer. It is not peace and plenty that man wants, but dominion. And yet in our complacent theories of society, we take no account of this instinctive and inherent lust for power, and we innocently assume that a people will be happy and contented if poverty is abolished, the labor problem solved, opportunity secured, and science and inventive genius given a free hand to increase wealth and material comforts.

Human beings are not so constituted that they will work contentedly in a standardized world, under scientific management and the rule of efficiency. By the inheritance of a half million years they are adapted to a different life, and while in the end their instincts may perhaps be changed, this can not be done in half a century.

IV

"Two things," says Nietzsche, "are wanted by the true man—danger and play." There is just enough truth in this to

set us thinking. The standardized world as planned for our future will offer us safety and work. In all the ages of man's slow development, he has never known safety. He has lived under the insecurity of war, of robbers, of plunderers, of tyrants, of flood and storm and famine. A safe world seems to him very attractive but it would be a foreign world.

And then, as regards work, it is assumed that, since unemployment is one of the evils of our present system, the problem will be solved provided we can devise some social plan by which regular work may be found for all. Surely it is a naïve inference that if work be provided for all, all will be happy. Man in all his past history has never been a regular worker. In our new social order, work is not only to be regular, but it is certain to be monotonous, for apparently the conditions of our industrial age are such as to make the work of the laboring man more and more of the monotonous and uninteresting type. We are already becoming aware of the discouraging and dehumanizing effect of monotonous labor in our highly specialized industries. Such regular and monotonous work is foreign to man's nature. Under it he frets and the "unrest" which everywhere we hear about breaks out in some form of social agitation, or in strikes, or in revolutions or more often in mere social delinquency.

There is, to be sure, one kind of work which from ages of habit is instinctive to man and under which he does not fret nor manifest unrest. It is typified in the planning and making of anything that he needs, such, for instance, as a canoe, a wagon, an automobile, a dwelling, a new tool, or in the planning and fashioning of a work of art. He experiences first the need of it, he plans it, he makes it, he uses or enjoys it. In such work he will put forth every power of mind and body, deriving therefrom the keenest pleasure and making no demands for higher wages or shorter hours. When we see children working unprompted and with might and main at some self-planned enterprise and gaining at the same time new strength and new courage and new vigor, but, on the other hand, quickly wilting under some lesser task enforced by parents, we speak of the perversity of childish nature. But there is no perversity about it, and there is no perversity either in the case of the unrest which follows upon enforced regular and uninteresting industrial labor. Nor is either case to be explained by referring it to "human nature." The key to the situation is found quite simply in racial history and racial habit.

We have here an instructive illustration of the failure in our plans for social reorganization to take account of psychological as well as economic forces. The society which we are planning for the future lacks the element of zest. Some shadow of romance it must have, if it is to abide; and this element of romance or zest can not be gained by providing eight hours a day for recreation and self-development. It is *life* that the people want, not recreation and self-development. What do the reformers of our social order usually have in mind for these eight hours of the day not spent in labor or in sleep. Libraries, no doubt, and art galleries and theaters and Chautauqua classes and moving pictures and gymnasiums and athletic games. But even a little knowledge of psychology should show us that these things do not satisfy human needs. All men and all women long for some kind of dominion, long to display their personal power, their personal charms, their personal genius. What they want is a career, a sphere of influence, a sphere of action; and in striving for these things they are restrained by no fear, not even fear of overturning the social order.

We hear a great deal in current discussions of social questions about social unrest, and the implication always seems to be that it is an evil and that contentment would be a good. But the reverse might be maintained with more reason. Unrest is the condition of progress. It betokens vitality. It is the symptom of a persisting urge that expresses itself in the will to live, in the will to power, in the will to freedom. Animal species, it seems, may remain fixed and static, but the human species must go forward or backward. When social unrest ceases, social stagnation may be expected to follow.

The society of the future, planned so largely from the economic point of view, makes little provision for the utilization of the two most powerful forces in the human mind, loyalty and devotion. Scientific management, conservation and efficiency are to take their place. The mind of man is so constituted by the conditions of his long history that he wants to be, and needs to be, loyal to some one or something, and devoted to some one or something, and only in this way is the best that is in him drawn out. He must have some *cause* to live for or to die for—some religion, some state, some flag, some woman, some lodge or labor union, or even some gang or band of outlaws. He wants to be, he must be, drawn out and away from himself to something which stands for an idea. This is *life*.

The social Utopias provide for existence, but not for life. It is the precipitous element that is left out of the reckoning.

A stable society in which there is a dreary routine of work and amusement will present problems as serious as those of the old system. A society in which there is no God to worship, no women to adore and protect, no state to defend, no wine to drink, no parties to fight for, no king to be loyal to, no classes to exploit, and no new lands to discover and conquer, might have some kind of happy beings for its citizens, but not *human* beings. They have a different history.

But, it will be asked, what *will* happen in such a society, for the march of events is surely and steadily in this direction. There *are* no more new lands to discover and conquer; kings and autocrats are out of date; alcohol has been condemned, and rightfully; women have demanded, and with perfect justice, the life of industrial activity and political equality, the God idea no longer enters deeply into the daily life of the people, wars between nations will, after this terrible war, no longer be endured; and internationalism is steadily supplanting nationalism. Well, surely no one knows what will happen, but it is conceivable that things may happen which will be worse than the evils we escape from. For instance, social unrest may increase until civil war takes the place of wars between states, as was near to happening in England before the present war. What would happen in such a society could at the best be predicted only if one knew whether vitality remained or did not remain among the people. Complete stagnation might ensue. Physical degeneracy might follow upon the increase of bodily comforts and there might be an increase of morbid sexuality, surrender to sensuous enjoyment, dancing crazes and moving-picture crazes, epidemics of crime and vagaries in religion and literature.

We are told that if war be abolished some substitute for war will have to be found. Yes, some substitute for war, and some substitute for alcohol, and some substitute for the state, and some substitute for the king, and some substitute for God, and some substitute for woman—and these substitutes will have to be provided still thousands of years, until the mind of man, five hundred thousands of years in the making, is made over.

Literature, poetry, the fine arts, will apparently have little place in the new social order, as it is planned. It is always assumed that they will be present and are to be *enjoyed*. But who will create these works of art. Art and literature spring

spontaneously from *life* in all its tragic incompleteness, not from an economically prosperous existence. They depend upon sacrifice, upon loyalty and devotion, upon courage and victory, upon sorrow and suffering, upon pain and renunciation, upon ministry and service to the sick and wounded. The question whether a world without so much sorrow and suffering would not be better, even if it should be a world without literature and art, is not the question we are here discussing, but only the question of adapting our new social order to the beings who are to live in it.

A certain wise teacher said that a man's life consisteth not in the abundance of the things which he possesseth. It consists partly in self-sacrifice. In our facile plans for the future of society, no place is found for sacrifice, yet in all the long history of mankind sacrifice has had a conspicuous part.

> Man has sacrificed himself for the state, woman has sacrificed herself for man.

No doubt the answer will be that it is precisely this unnecessary sacrifice to which we wish to put a stop. But here much depends upon the meaning of the word "unnecessary." It may be economically unnecessary, but it may be spiritually, morally, even socially or racially, altogether necessary. It is possible to gain many worthy economic values and lose many still greater spiritual values, to gain the whole world and lose our own souls. There is at least some truth in the saying that he who loseth his life shall find it.

But the loss of the spiritual life and the vulgarization of humanity might be merely incidental features in the new society. The question which we are really interested in here is whether man, as he is mentally and physically constituted, will be able to live at all in such a social state as is planned. Apparently he is usually pictured in his self-owned home, surrounded by his healthy, happy family, working six or eight hours a day, and otherwise cultivating his garden or wending his peaceful way to the public library or art gallery, or "improving his mind" by attending evening classes. And if the disquieting question does arise whether he will behave in this manner, one class of romancers says that he will do so provided that it is physically impossible for him to obtain access to intoxicating drink. Another that he will do so provided that his mother, wife and daughter have an equal voice in public affairs. Another that he will do so provided that the state takes over many functions now belonging to individuals. Another that he

will do so provided that he can have the reins of government entirely in his own hands, free from every kind of oppressive autocracy. As a matter of fact, it will depend very largely upon the structure of his brain and the balance of his whole personality. National prohibition, votes for women, socialism, the world for democracy, will have little to do with it. No doubt these are all good and all important. At any rate, they are all impending. But they are not the determining factors.

V

What conclusion then are we to draw from this consideration of psychological forces, as against the economic, social and political forces which rule the thinking of our time? Is the old society good enough with its political rivalries and its incessant wars, with its priests and its sisters of mercy, with its drunkenness and crime, with its women as ornaments and dolls. Some of these things, at any rate, are outgrown. War is now racially, as well as economically, too expensive. Alcohol is a narcotic and poison, not a stimulant, as was once believed. Woman has outgrown the doll stage. We shall not go back to these things. But, nevertheless, it is a misconception of life that places the emphasis of the future upon peace and plenty, upon economic expansion, upon equality, upon comforts, and luxuries, and wealth, no matter how equitably the wealth is distributed.

This mistaken emphasis in almost all our plans for social reconstruction goes back to Francis Bacon. As Lord Macaulay said,

> It was not Bacon's purpose to make men perfect, but to make imperfect men comfortable.

Bacon's ideal has been realized. Men have gained comfort, but they have gained no physical, mental or moral perfection. We are planning in the twentieth century to make them still more comfortable, while giving little thought to making them perfect. And comfort is a dangerous legacy for man.

It would seem, therefore, to be well to think along other lines for the future. How may we make men better? Civilization does not depend upon the increase of wealth, or its equal distribution. It depends upon the proportion of dominant and effective men and women, upon the production of leaders possessing initiative, daring, creative and constructive power, and it depends upon discipline, poise, loyalty, devotion and mental and moral health. With the increase of wealth, on the one

hand, and the increase among the people as a whole of the proportion of defectives, or even of ineffectives, and with the startling increase of social diseases, our glittering civilization may be near the fate of other civilizations of the recent past. And if our present civilization does go down, there are apparently no reserves of vital power in the outlying districts of the earth, as there were in the days of Rome, to replenish the impoverished blood of the people, for the effectives of all races are now drawn to the great industrial and commercial centers and their vigor exploited for the glory of the present day, not for racial conservation.

It would seem, therefore, that our endeavor must be in the direction of eugenics and education, and that in our efforts at social reconstruction we must think along these lines rather than so exclusively upon economic, political and social questions. The world will be made safe for democracy only when the people of the world are made fit to live in a democracy.

GALL INSECTS AND THEIR RELATIONS TO PLANTS

By E. P. FELT

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ABUNDANT food, protection from adverse natural agents and minimum exertion are ideals cherished by many. The first two appeal strongly to the infant, the second to the growing child, while the third may become increasingly dominant with the progress of adult years. Solomon advised the sluggard to go to the ant, probably because he had no sympathy with physical or mental inertia; otherwise he might have said: "Consider the gall insect; it does not sow, yet it reaps; it does not build, yet it is sheltered; it gives nothing and receives abundantly."

Easy living is attractive and it is not surprising to learn that representatives of a number of large groups of insects have developed in this direction. In other words, the term "gall insects" does not represent a systematic entity; it is an assemblage of diverse forms grouped because of similar habits. Before proceeding farther, let us agree as to just what is meant by the term "gall." Insect galls may be defined as vegetable excrescences resulting from insect activities and usually sheltering the immature stages of the producers, though a wide acquaintance with these growths demonstrates the existence of innumerable gradations between the apparently normal and the decidedly abnormal, and as a consequence it is difficult to establish a satisfactory distinction between insect galls and deformations not worthy of classification in this category. Some would include the mere curling of leaves and while to a certain extent this is justified, in most cases, unless the curling is pronounced, the deformation has not been considered as an insect gall. Galls caused by insects and their allies are known as Zoöcecidia; those produced by plants are termed Phytocecidia.

The origin and development of these growths are not less interesting than the deformities themselves. The gall-making habit among insects has undoubtedly developed independently in several widely separated groups and must have originated

in a mutual reaction between the insects and their host plants, which has reached its climax in many apparently inexplicable deformities of the present day. All stages of the process may be observed among the gall midges, some of which live among succulent fungus growths and either feed a little upon the fungi or obtain nourishment by absorption from the humid surfaces of the host. There are certain predaceous maggots in this group which have the mouth parts greatly prolonged and apparently especially adapted to withdraw by suction the body fluids of their hosts. It may be one or the other or possibly a combination of the two methods which obtains among the fungus-inhabiting forms. It is only a step from this to absorption with apparently no mechanical injury, as in the leaf spot gall of the soft maple or the pod leaf galls of ash and spiraea. The habit once started, it is possible to understand how the process might continue with indefinite variations among a host of species, which is just what has taken place. The adaptations have continued along a number of lines to such an extent that many gall insects live at the expense of their hosts and in some instances, at least in the case of certain plant lice, the mere satisfying of the primitive pangs of hunger seems to be all that is necessary to compel or cajole, as it were, a host plant to grow or throw around its enemy a defensive barrier or gall within which the aphid may live in the presence of abundance, be comparatively safe and obtain like conditions for its numerous progeny. This sheltered, luxurious type of existence appears to be essential to many species and the tendencies along these lines have developed to such an extent that twenty-nine species of gall-making aphids, Phylloxera, are known to live at the expense of our hickories and in a similar manner a number of species of jumping plant lice, Pachypsylla, subsist on hackberry.

Before going further, let us glance for a moment at the different types of insects possessing this gall-making habit.

The Hymenoptera, best known because of the industrious honeybee, has two important families, the Cynipidæ and the Tenthredinidæ, members of which live in this questionable manner. The first named are minute, four-winged gall flies with legless white maggots. They are moderately numerous in species and remarkable for an alternation of generations; the structural variations between the adults in different generations being so marked, that before the relationship was suspected, they were referred to separate genera. Certain

Cynipids or gall wasps are believed to reproduce only by parthenogenesis. These little insects display a marked partiality for oaks and roses and produce striking types of galls, such as the cortical swellings of the gouty oak gall,[1] a species occasionally becoming so abundant that five hundred thousand individuals may be reared from one tree and its conspicuous galls form giant, bead-like swellings on almost all the smaller branches of a large oak. Occasionally the peculiar bud-like swellings of *Andricus gemmarius* Ashm. are very abundant on pin oaks and the sweet exudation issuing therefrom attracts hosts of bees, flies and similar insects. Another oak gall occasionally numerous is the oak leaf stalk gall.[2] The gall of the wool sower[3] is another striking type and results from the female depositing eggs in a ring of buds around white oak stems, and from the series of wounds inflicted, there develops a seemingly delicate, globose, white, pink-spotted mass which on examination is found to consist of numerous cells, each supported and guarded by a thick fungoid, hairy growth. A more ordinary type may be seen in the familiar banded bullet gall,[4] a representative of a considerable series generally known as "bullet galls."

The gall wasps or Cynipidæ attack plants referable to only six botanical families and but eleven plant genera. There is, however, the most striking limitation in food habits, since a very large proportion of the 445 gall-makers subsist at the expense of the oaks, 38 species have been reared from members of the rose family, 28 of these being species of the genus *Rhodites* and found only upon the rose. The other species of gall wasps are scattered in their food habits, the most evident concentration, and this far from marked, being the 12 species reared from various compositae, the genera *Silphium* and *Lactuca* supporting four and three, respectively.

The gall-making sawflies or Tenthredinidæ produce a great variety of swellings on the willow, mostly upon the leaves. The galls made by these insects exhibit a great proliferation of tissues without distinct layers, according to Dr. Cosens, and are easily recognized by the caterpillar-like inhabitants. The latter are readily distinguished from true caterpillars or Lepidopterous larvæ by the greater number of prolegs. Certain galls, at least, produced by members of this group develop

[1] *Andricus punctatus* Bass.
[2] *Andricus petiolicola* Bass.
[3] *Andricus seminator* Harris.
[4] *Disholcaspis fasciata* Bass.

to a considerable extent before the eggs hatch—a hypertrophy resulting probably from chemical stimuli produced by fluids in or deposited with the eggs and transmitted by osmosis.

The beetles or Coleoptera are so respectable that relatively few species of three families, namely, the Buprestidæ or metallic wood borers, the Cerambycidæ or long-horned wood borers and the Curculionidæ or weevils, live in galls. The deformities are largely the result of mechanical obstructions or stimuli and present little of special interest. The representatives of several families of moths or Lepidoptera, the Sesiidæ, the Gelechiidæ and the Tineidæ produce galls of the mechanical type and as in the beetles, the habit is by no means general.

Two families of the Diptera or two-winged flies are noted for their gall producers, namely, the gall midges or Itonididæ and close relatives of the fruit flies or Trypetidæ. The first named is the banner group among gall insects and are ancient and of presumably honorable lineage, since remains of a number of genera and species have been found in the Baltic amber, two species have been discovered in the tertiary Oligocene beds of the White River, while a Pleistocene swamp deposit of Maryland contains swellings upon the leaves of the bald cypress which, in the opinion of Dr. Howard, were produced by a gall midge. This large family of small flies contains some nine hundred known American species, this being probably only a third or a fifth of the fauna. These delicate midges range in length from 1/4 to 1/50 of an inch and present marked diversities in habits and structures. There are striking differences in food habits between this large group of gall-making midges and the gall-making wasps referred to above.

In the first place the 679 galls produced by midges occur on plants belonging to 69 botanical families and 202 plant genera. The larvæ of 66 species live at the expense of the Salicaceæ (52 occurring on willow); 29 species subsist upon the Juglandaceæ, all but one infesting hickory; 42 attack members of the oak family (35 of these being upon oaks); 56 produce galls on the Rosaceæ; 24 on the Legumes, 22 upon the grape and close allies and 150 on the composites. The most obvious concentration of species, aside from those mentioned above, is the 44 midges reared from golden rod and the 22 found upon aster. These approximate figures indicate that the group has been able to maintain itself upon a great many different plants through a considerable physiological adaptability and that the distinctness of the species has been established by relatively small modifications in structure.

Different Types of Galls: *A.* Linden mite gall, sometimes very abundant on basswood leaves, note the varied forms. The interior is inhabited by microscopic plant mites. *B.* Maple spot gall, a yellowish-red margined gall, very common on soft maple; at the center there is an almost transparent maggot. *C.* Bud gall on the western rayless goldenrod, note the protecting brush of plant hairs shown in the enlarged section. *D.* Goldenrod ball gall, very common, each inhabited by a large stout yellowish-white maggot. *E.* Cypress flower gall, a peculiar whitish flower-shaped growth sometimes very abundant on the twigs. *F.* Cockscomb elm gall, a deformity produced by a plant louse and occasionally very abundant on small trees, the slit-like entrance on the under surface of the leaf is shown in the upper right-hand figure. *G.* Downy flower gall, sometimes very abundant on goldenrod. *H.* Witch hazel cone gall, a greenish or reddish gall, sometimes very abundant and produced by a plant louse.

A few galls of the Trypetidæ are well known, particularly the common globular stem swelling on golden-rod known as the golden-rod bullet gall.[5] This deformation is simply a stem swelling about an inch long containing near its center a yellowish-white legless maggot.

The Agromyzidæ, another Dipterous family comprising small and usually overlooked flies, has several rather common though generally ignored gall makers. Oval subcortical swellings upon willow and poplar twigs are frequently abundant. Those on the willow may be produced by a sawfly larva, though we have yet to obtain from the poplar twig gall any other maker except *Agromyza schineri* Giraud.

Most galls produced by Diptera are closed and are easily recognized by the legless maggots inhabiting them. The larvæ of the gall midges are peculiar in the possession of a so-called "breast bone" or "anchor" process, though this structure is not evident in all gall midge maggots, especially the very young stages.

The true bugs or Hemiptera have well-known gall-makers in two families, the plant lice or Aphididæ and the jumping plant lice or Psyllidæ. The former is a large group with occasional species producing galls upon a great variety of plants. Species of jumping plant lice, *Pachypsylla,* inhabit a variety of leaf and stem galls on the hackberry, being strictly limited to this host.

Hemipterous galls are characterized by an opening due to the fact that in some cases, at least, the tissues grow up over and nearly enclose the founder of the gall and eventually form a hollow mass of living tissues with the inner walls nearly covered by plant lice, a condition strongly suggesting the geode of the mineralogist. Certain species of *Phylloxera, Pemphigus* and *Chermes* inhabit characteristic and rather common galls. Some of these species produce a considerable series of generations each year and certain of them may inhabit very diverse galls upon entirely different food plants. One of the most interesting of these is the maker of the spiny witch-hazel gall[6] with its summer generations developing upon and corrugating the leaves of birch. The complicated life history of this insect has been carefully worked out by the late Theodore Pergande, a painstaking student of various plant lice.

The plant mites or Eriophyidæ comprise an important division of the *Acarina* and are best known because of the sack-

[5] *Eurosta solidaginis* Loew.

[6] *Hamamelistes spinosus* Shimer.

CHARACTERISTIC OAK GALLS: *A.* Bud-like galls on oak twigs, sometimes very abundant and since they produce a sweetish fluid, hosts of bees, flies and other insects may be attracted in early summer. *B.* Oak spangles, produced by a gall midge, note the cup-like shape and the little oval cavity at the base, shown in the illustration of a sectioned gall. *C.* Large oak apple, one of the more common and striking galls produced by gall wasps. *D.* Gall of the wool sower, a delicate appearing white, pink-marked wooly growth containing seed-like cells, each inhabited by a white maggot. *E.* Mid-rib tumor gall sectioned to show the series of cells inhabited by the white maggots. *F.* Small oak apple, the one in section shows the characteristic central cell inhabited by a maggot and supported by numerous radiating fibers. *G.* A peculiar cylindrical-spined, rosy red, yellow-banded gall on a western oak. *H.* Gouty oak gall, a large swelling frequently forming bead-like enlargements on most of the smaller branches of various oaks, large trees sometimes being badly infested.

like or hairy galls so common on the leaves of certain trees. The microscopic size of the mites renders their study difficult and this has been a serious hindrance to investigators. There are now listed 161 deformations produced by these minute forms and much remains to be learned concerning American species.

It is evident from the preceding that the gall-making habit has arisen independently among structurally widely separated groups. The underlying causes are the plasticity of vegetable tissues and the adaptability of animals. The insects have simply followed the lines of least resistance. The abundance of individuals and the multiplication of species are closely related to the food supply and insect adaptability. The greater the latter and the wider the range of food habits, the better are the chances for an abundant life so frequently observed in nature. This phase of the subject has interested the speaker for several years and he would review briefly the conditions found among the gall midges.

They comprise an enormous family of small forms, mostly gall-makers. The more generalized present close affinities with the fungous gnats and like them live on fungi or in decaying vegetable matter. *Miastor* and *Oligarces*, two ancient types of gall midges, live in the decaying bark of various trees and in their larvæ we find that form of parthenogenesis known as pedogenesis; that is, maggots produce maggots directly, the egg, pupal and adult stages being eliminated for an indefinite number of generations. Incidentally this biological short cut is an advantage to the species, since it permits multiplication in the remote, narrow crevices of decaying wood, places inaccessible alike to adult midges and to many parasites and predaceous enemies.

By far the largest number of the gall midges are gall-makers, and these are easily distinguished from the lower forms by the greatly reduced first tarsal segment and the presence of circumfili. These latter are also known as "arched filaments" and "bow whorls" because of the remarkable series of loops they form on the male antennal segments in the most specialized tribe. A few of the more generalized tribe, the Epidosariæ, live in dead, occasionally rather dry woody tissues, some being associated with true gall-makers.

The importance of the bud gall in the biology of gall insects is well shown by a tabulation made a few years ago listing 46 as inhabitants of fruit galls, 145 in bud galls, 150 in leaf galls

and 96 in stem galls out of a total of about 437. Fruit galls are potentially bud galls, so that in reality 191 of these were bud galls. *Rhabdophaga* is a genus with a marked preference for willow, and in this we have 12 species inhabiting bud galls, 12 in stem galls and 3 in leaf galls. Though apparently not conclusive, the evidence in this case is really in favor of the bud gall, when we realize that most species of *Rhabdophaga* live on willow; and after making allowance for the softness of the shoot and the rapidity of the growth, it is perhaps surprising that no more primarily bud inhabiting species find themselves left in the race with the plant, as it were, and issue from a deformity which would ordinarily be classed as a stem gall.

The subject is of such interest as to justify further examination. There are two peculiar fusiform galls on narrow-leaved golden-rod, the golden-rod ribbed gall[7] and the golden-rod stemmed gall,[8] both of which may be found among the florets, on the young leaves and the younger portions of the stem, indicating that the parent midges oviposit in the bud and that here, as in the willow, it is not the fault of the insect if the progeny do not issue from bud galls. Another case is that of the nun midge,[9] a species normally breeding in buds and also issuing from deformed flower heads of both golden-rod and aster, and most interesting of all, from small oval cells between two adherent leaves of golden-rod. These latter start while the leaves are in the bud, and as the growth of the plant is hardly affected, it is easy to find in the field these leaves united at the point of injury, with the petioles in all stages of separation; in other words, the upper portion of the stem develops and separates bases of leaves which in the bud are nearly contiguous.

The question of bud infestation does not end here. Some ten species of Cincticornia have been reared from various leaf galls on oaks, the deformities being scattered irregularly over the surface. Some of these galls never develop beyond the blister stage and others form conspicuous, more or less globular, reddish swellings. The primary infestation, we are convinced, occurs while the plastic leaf tissues are in the bud and the same appears to be true of the 18 different leaf galls of *Caryomyia* on *Carya*. These two genera alone give 28 potential bud galls and turn the balance most strongly in favor of the plant bud as the primary source of such deformities. It

[7] *Rhopalomyia fusiformis* Felt.
[8] *Rhopalomyia pedicellata* Felt.
[9] *Asphondylia monacha* O. S.

may be well to add here that the needle-tipped ovipositor of *Asphondylia,* preeminently a bud-inhabiting genus, appears particularly fitted to probe or pierce tender bud tissues.

It happens that over half of the stem galls produced by reared American gall midges result from the activities of the Lasiopterariæ, a highly specialized assemblage producing 52 stem, 12 leaf, 2 bud and but 1 fruit gall. This fact suggests that a high degree of specialization among gall midges is prerequisite to the successful invasion of the harder tissues of the stem.

The fruit gall, botanically speaking, is nothing more than a restriction of attack to flower and fruit, rather than to leaf buds, with such a slow or late development of the insect that the deformity appears in the fruit rather than as a blasting of the blossom. There are a number of seed-inhabiting gall midges. The pear and the fruit of our wild cherry are also subject to attack by members of this group.

Leaf galls include a large number of deformations. The simplest type is a leaf roll, such as the marginal fold gall[10] on oak. Leaf rolls may be rather loose or comparatively tight. Vein folds are common, one of the most abundant being the ash midrib gall,[11] which is simply a large tumid thickening of the midrib on ash leaves. Enlargements of leaf veins may be limited to a rather definite situation, as in the case of the purple vein midge,[12] or they may fuse with irregular enlargements of adjacent tissues and produce a swelling like the grape tomato gall,[13] rather common on leaves and tendrils of grape.

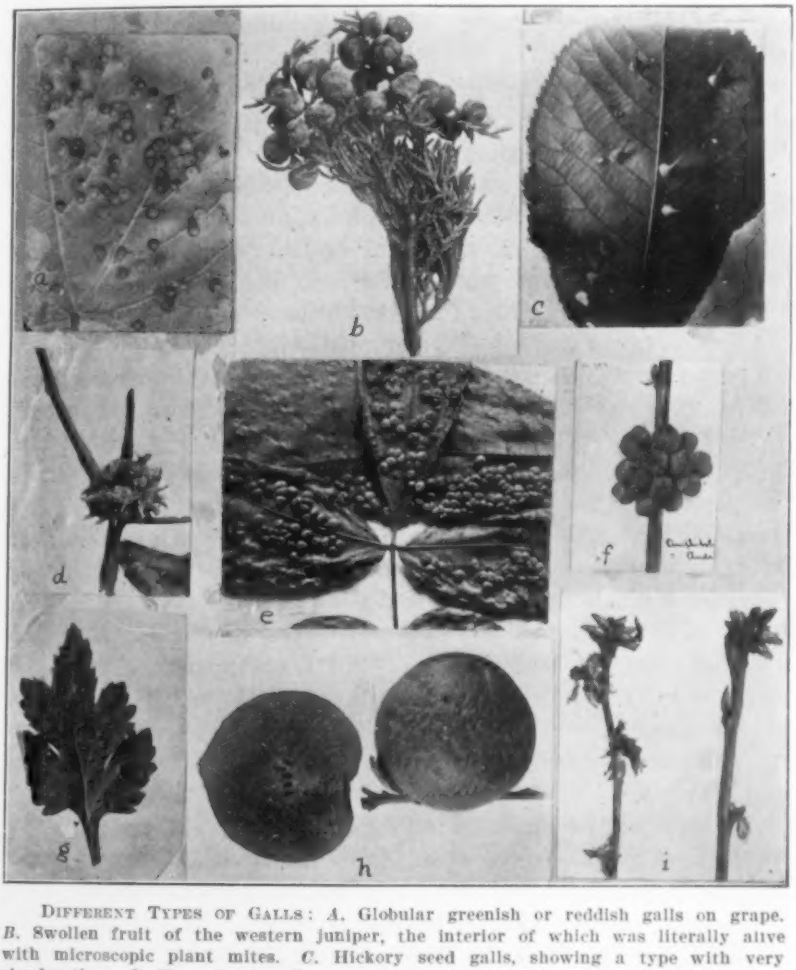
The leaf tissues between the veins may be invaded, one of the simplest types being a small pustule on the oak produced by *Cincticornia simpla* Felt. This may be extended to form a mine as in the purple leaf blotch[14] on *Cratægus* or as a result of the proliferation of tissues develop into a globose, conical or even cylindric swelling.

Stem galls may be classed as medullary and subcortical, the former occurring mostly in herbaceous vegetation and in the smaller limbs or shoots of shrubs and trees. They may be inhabited by one or more larvæ, which usually occur in a more or less definite channel along the pith, as in the case of the aster stem gall.[15] The subcortical type of gall is common in

[10] *Itonida foliora* Rssl. and Hkr.
[11] *Contarinia canadensis* Felt.
[12] *Sackenomyia viburnifolia* Felt.
[13] *Lasioptera vitis* O. S.
[14] *Lasioptera excavata* Felt.
[15] *Neolasioptera ramuscula* Beutm.

herbaceous plants and is the predominant type of stem gall in woody plants. It is generally polythalamous, frequently eccentric and, as stated earlier, is usually produced by a rather highly specialized gall midge.

Only a few species are known to produce root galls, probably because of the greater difficulty in finding them. There seems to be no marked difference between root and stem swellings aside from their location.



DIFFERENT TYPES OF GALLS: *A.* Globular greenish or reddish galls on grape. *B.* Swollen fruit of the western juniper, the interior of which was literally alive with microscopic plant mites. *C.* Hickory seed galls, showing a type with very slender tips. *D.* Horned oak gall, a peculiar growth on oak twigs, with harder horn-like projections within which the whitish gall wasp maggots live. *E.* Typical hickory-leaf midge galls showing extreme abundance. *F.* A peculiar clustered bud gall on oak. *G.* Galls of the chrysanthemum gall midge, a recently introduced and very destructive European species. *H.* Apple-like oak gall, a western giant with a diameter an inch to an inch and a half. *I.* Elm bud galls, many midges and gall wasps live in buds and prevent their development.

Malformations produced by gall-midge larvæ appear to result largely, if not entirely, from mechanical or chemical stimuli produced by the larvæ. The size of the gall is, generally speaking, proportional to the number or size of the larvæ and with the death of the active agent, development of abnormal tissues soon ceases. This is particularly well marked in the beaked willow gall,[16] the aborted ones producing only parasites. There is a close relation between the midge and its gall and, generally speaking, a series of flies reared from the gall are the true producers, though inquilines and predaceous gall midges are by no means unknown. For example, the grape tomato gall may produce five species of midges referable to as many genera and the same is true of the swollen wild cherries inhabited by midge larvæ.

Certain genera of gall midges are predaceous, this being well marked in the genus *Lestodiplosis*, an enemy of other gall midges; *Aphidoletes*, an enemy of aphids; *Mycodiplosis*, some species of which prey upon scale insects, and *Arthrocnodax*, with a marked preference for plant mites.

The larvæ of gall midges are mostly legless, usually yellowish or yellowish orange, sometimes nearly transparent and generally with a well-developed "breast bone" or "anchor" process. This structure and the supernumerary segment just behind the head are characteristic. These maggots also have the power of throwing themselves some distance; the two extremities are approximated and then extended with a snap that projects the larva into the air. Midge larvæ living exposed upon leaves usually develop some protective device such as a series of tubercles, as in the case of the larva of the gouty pine midge,[17] after it leaves the gall. The transparent maker of the maple spot gall[18] is another striking example of protective modifications.

The minute size of gall midges, the difficulty of rearing them and their marked fragility have resulted in more attention being paid to the galls than to the insects. The producer in most cases is more interesting than the product and we wish for just a moment to call attention to some of the more striking features of the 900 species belonging to over 70 genera.

The antennæ are unusually interesting structures, the normal number of segments is probably 16, though a very large proportion of the gall midges have but 14 antennal segments.

[16] *Phytophaga rigidæ* O. S.

[17] *Itonida inopis* O. S.

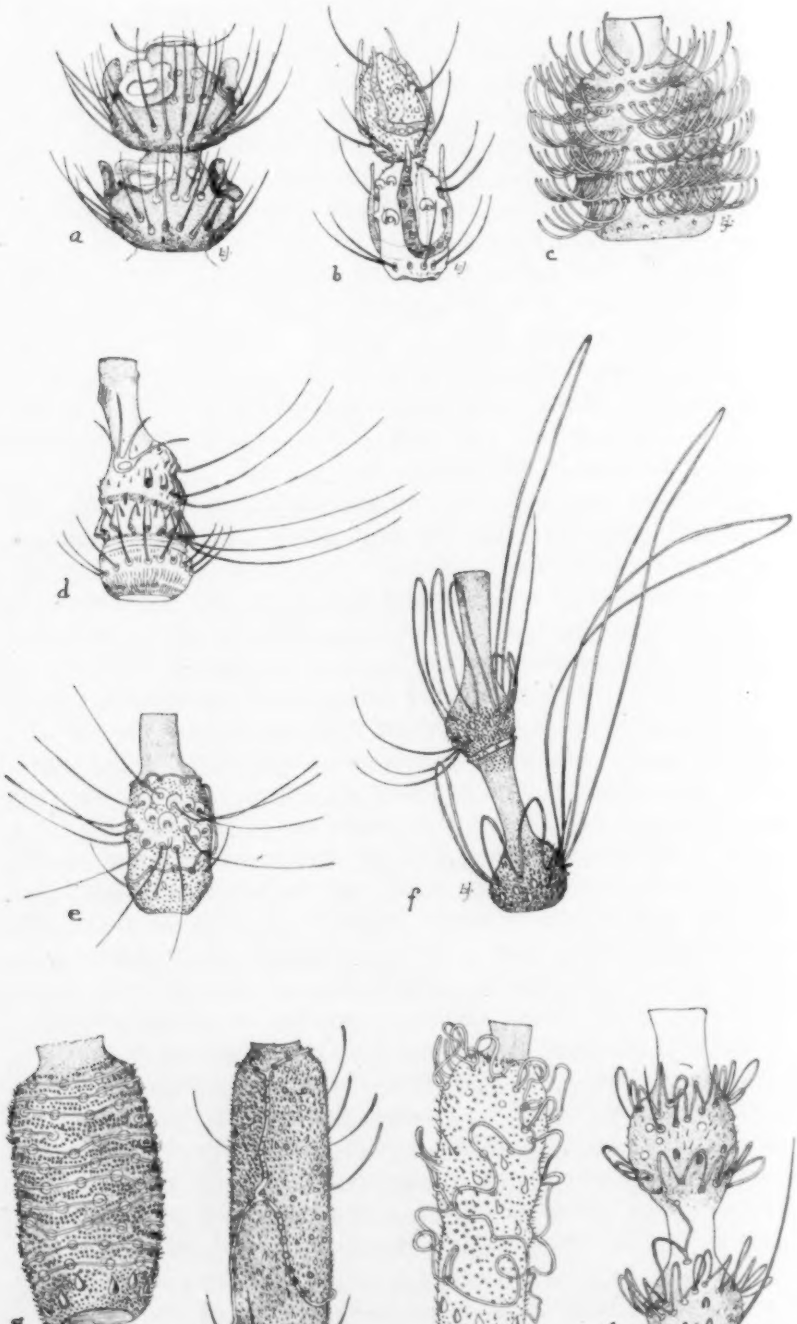
[18] *Cecidomyia ocellaris* O. S.

The extremes range from but eight in *Tritozyga* and *Microcerata* to thirty-three in *Lasioptera querciperda* Felt. These segments vary from relatively simple cylindric units with no particularly efficient sense organs to dumbbell-shaped structures with highly specialized "bow whorls," "arched filaments" or, as we prefer to call them, circumfili.

The more generalized midges are inhabitants of decaying organic matter and bear on their antennæ a variety of olfactory organs. The most interesting of these are the stemmed discs of *Monardia*, though in the same tribe we have the subapical flaring collars and in certain Lestremiinæ striking digitate processes; crenulate whorls are peculiar to the Campylomyzariæ, a simple type being seen in *Corinthomyia*, while the more common and probably the more highly specialized form is to be seen in *Prionellus*.

The "bow whorls," "arched filaments," or circumfili are exceedingly peculiar. In the first place, these homogenous structures have markedly different optical properties from the usual sensory hairs or setæ and are invariably connected in series of low or high loops, the union between the component elements being so perfect that there is no sign of division, no perceptible enlargement and no indication of weakness. They reach their maximum development in the male Diplosid and are characteristic of the most specialized subfamily (Itonididinæ) of the gall midges. The primary type is a low subbasal and subapical circumfilum united on one face of the segment by a nearly longitudinal filum. One of the most peculiar is the horseshoe-like modification, nails and all being simulated, on opposite faces of the antennal segments in *Winnertzia* of the Epidosariæ, a tribe with a marked tendency to hyperdevelopment of these structures. The males of *Asphondylia*, *Schizomyia* and *Cincticornia* also show peculiar modifications.

Males of the most specialized tribe (Itonididinariæ) exhibit the extreme development of these sturctures. They may have two or three whorls of long loops, the former we have designated as the bifili, the latter as the trifili, believing this subtribal division worthy of recognition. In each of these subtribes we may find among the males genera with relatively low loops as in *Thecodiplosis* and *Hormomyia* and many with extremely long loops, such as *Contarinia* and *Bremia*, the latter remarkable because of the great prolongation of two loops and especially on account of the thread-like middle circumfilum characteristic of the female.



TEE ANTENNÆ, OR FEELERS OF INSECTS, are highly developed sense organs and the

We may also note that the palpi of the gall midges vary from well-developed four-segmented organs, nearly as efficient as the greatly reduced antennæ of some genera, to minute rudimentary lobes, and in one or more species these organs seem to have disappeared. This tendency toward reduction has arisen independently in several widely separated genera.

There is likewise great modification in the number of tarsal segments, they ranging from one to five; the entire subfamily Itonididinæ having the first tarsal segment greatly reduced. There are certain American genera where there is a reduction in tarsal segments from five to four, to three and in one to two tarsal segments.

The wings, organs which might be expected to respond to environmental agencies slowly, show variations from a structure with five or six veins to one with but one or two veins and in a few extreme cases there are none. The female of one European species has lost the organs of flight.

The association of characters in gall midges is so marked that the presence of one structure means the existence of others and indicates a probable similarity of habits. The *Campylomyza* wing postulates, the long first tarsal segment and larvæ feeding for the most part in dead organic matter, the well-developed crossvein, the short first tarsal segment and the tendency toward the bizarre in the circumfili indicate the Epidosariæ, a group confining itself largely to dead organic matter. The generalized wing of *Rhabdophaga* with the comparatively simple antennæ, quadriarticulate palpi and toothed claws defines a dominant willow group, while the similar *Rhopalomyia* with its reduced palpi and simple claws insistently murmurs solidago buds. *Asphondylia* with its peculiar antennæ, reduced palpi and aciculate ovipositor is satisfied with practically nothing except buds, while the related *Cincticornia* with its

above illustrations give some idea of the wonderful variety of structure to be found in the gall midges. Gall-midge antennæ may be composed of from eight or nine to thirty-four jointed elements or segments. The simple cylindrical segment is indicated in Figs. *G*, *H* and *I*. The same with a stem-like projection is shown at *D* and *E*, while the greatly modified dumbbell type is seen at *F* and *J*. These organs bear peculiar sensory structures, such as stemmed disks, shown at *A* and finger-like or digitate processes near the tip at *D*. There may be few or numerous short or long hairs and in the case of *C* these hairs may be modified into series of stout curved growths running around the segment. Among the most peculiar structures found on the antennæ are the "arched filaments" or "bow whorls" or circumfili. These may be low and few in number as at *E* and *H*, numerous as in *G*, somewhat higher as in *I*, still longer as in *J*, or enormously produced as shown in *F*. One of the most peculiar modifications of the bow whorls is the horseshoe-like structures, nails and all, represented on the two segments illustrated at *B*. These bow whorls under a microscope are very different from the ordinary hairs. The illustrations are all made at approximately the same enlargement and with the exception of *A* and *B*, each figure represents one segment.

quadriarticulate palpi must have oak leaves in the bud and the peculiar *Caryomyia* insists upon hickory.

There are three important groups of gall-makers, the gall midges responsible for 679 deformities, the gall wasps remarkable for their high specialization and the peculiar and extremely interesting alternation of generations inhabit some 445 galls, while plant mites have been listed from 161 galls. The host preferences of these numerous forms are very marked, as evidenced by the following tabulation:

PRINCIPAL HOST PREFERENCES OF AMERICAN GALL INSECTS

Hosts	Gall Midges	Gall Wasps	Gall Mites
Pines and cedars	35		
Grasses	33		
Willows	66		23
Oaks and chestnut	43	353	17
Rose family	56	38	27
Legume family	24		
Maples	13		34
Grape and Virginia creeper	22		7
Composites	150	12	3
Total for all plants	679	445	161

It is obvious from the above that a close correlation must exist between plants and gall-making insects which live upon them. Generally speaking, groups of plants presenting numerous widely disseminated, closely related forms are acceptable hosts to many gall insects and frequently the members of one order, of a tribe, or even a genus may be closely limited to such plants and in some instances to species or closely related species. For example, gall wasps attacking red oak and its allies are not found on the white-oak series, and vice versa. This great diversity in structure and habits of gall insects is evidently a response to environment and is made necessary by the physical unfitness of adults or larvæ to withstand other conditions. These insects are small in size, fragile, local in habit, mostly slow of flight and generally far from being unusually prolific. Nevertheless, hundreds of species are able to maintain themselves, frequently in large numbers, in spite of apparently unfavorable conditions.

It must not be concluded from the above, lengthy though this may be, that there is nothing yet to learn about gall insects and the deformities they inhabit. New species and new genera are awaiting discovery, the biology of many gall insects and especially of gall wasps is still unraveled. The great variety

of galls upon the oaks, many of them attractive in color, delicate in texture and comparatively unknown, challenge our admiration and incite to further study. The same is true of the many and varied deformities inhabited by the fragile gall midges, species which have learned to subsist upon various parts of a large variety of plants. The gall mites, microscopic though they are, invite the attention of the student.

Insect galls are to be found in all parts of the country and they and their makers present a charming and delightful field of study which may be entered with profit by the child at school as well as by the student of more mature years.

The poet must have dreamed of some such condition when he wrote:

> And Nature, the old nurse, took
> The child upon her knee,
> Saying, "Here is a story book
> Thy Father has written for thee."
>
> "Come, wander with me," she said,
> "Into regions yet untrod;
> And read what is still unread
> In the manuscripts of God."—LONGFELLOW.

THE BROOK STICKLEBACK

By Dr. E. EUGENE BARKER
NEW YORK STATE COLLEGE OF AGRICULTURE

IN some of our shallow, weed-choked pools and ditches there lives a most interesting little fish—the brook or five-spined stickleback (Eucalia inconstans), Kirtland. He is so well accustomed to living in stagnant water that he can easily be transferred to an aquarium where he thrives well and is sure to prove an interesting pet. He is diminutive in size—the largest adults measuring barely over one and one half inch in length. The males are bright in color, having a veiling of black over an olive-green ground color which lightens to yellow on the belly. The females are somewhat lighter in color. They are extremely pugnacious little fishes, and show resentment when another fish approaches, even one of their own kind. The spines on the back bristle up like hiars on a dog's back, and with a vicious lunge, the tiny bit of fury rushes, open-mouthed, at the innocent intruder. Often the fish's emotion is registered by a dark flush that sweeps over his body for the time being. It is interesting to note that, when these fishes are transferred to a light or a dark bottom, the color changes in accord with the background. They are voracious feeders and thrive on bits of angleworms, or of fresh meat if it is cut into fine enough pieces.

Like other members of the stickleback family, the brook stickleback is most interesting, perhaps, in his family habits. A true nest is built by the male in which the female deposits her eggs, and the male remains on guard to protect it until after the young have hatched. Some species nest readily in the aquarium, but the brook stickleback has not been observed to do so, at least as far as the writer's experience and knowledge go. On one occasion, however, a male fish was seen guarding his nest in a pond. He was captured and brought home and placed in an aquarium, together with his nest and its contents. As soon as all was settled he assumed again his proprietary air and stood guard over the little home and its precious contents. At one side of the nest there is almost always a small hole through which the eggs can be seen inside it. This fish often approached the opening, and if any of the

eggs protruded from it he took them into his mouth, and, backing away a short distance, blew them back again securely into the nest. He swam constantly around the nest, from time to time coming close to it and beating his pectoral fins rapidly like the wings of a hummingbird as it poises before a flower; he would thus draw a current of water through the nest and

THE BROOK STICKLEBACK

aerate the eggs. If any other fish were put into the aquarium, even a female of his own species, he would bristle, flush dark and dart viciously at the stranger and chase it away from the vicinity of his nest.

In the wild state, nesting is begun while the water is still at a low temperature, between 40 and 50 degrees Fahrenheit, although in the shallow surface water, at the margin of a pool where the nest is always built, the water may be as warm as 70 degrees. In central New York State nesting may begin before the middle of April. It continues until late in May. The nest

itself is a very dainty structure. It is always built of the materials at hand, which, of course, renders it inconspicuous, indeed, almost invisible amidst its surroundings.

The first nests are built before vegetation has begun to grow in the pools. The only suitable materials that the builder finds at hand are fine fibers, blades of dead grass and the like. These are loosely woven together and held in place by means of a thread which is produced by the male (as in other species of stickleback) from a secretion of the kidneys. It coagulates and hardens upon contact with the water, thus forming a thread suitable for binding together the materials of the nest. As the season advances and vegetation begins to appear in the pools, the nests are made mostly of green algæ, sometimes with sprouting seeds upon them. They are delicate little structures, spherical in shape, about three quarters of an inch in diameter, and with a small round hole on one side through which the eggs are placed within the nest. This little round ball of a home is tethered to a rootlet, submerged blade of grass or some similar attachment, and appears so much like a bit of the general mass of debris around it, or the masses of green algæ, that it can be discovered only with the greatest diligence.

The eggs are about 1 millimeter in diameter, transparent and light yellowish in color. They hatch in about eight or nine days when the water is as warm as 65 degrees. The young fishes are about 5 mm. long when they hatch. At first they still have a very large yolk-sac attached to them which contains enough nourishment to keep them for several days. It soon is all absorbed, however, and the tiny fishling grows fast. For the first few days he attaches himself to some still object by the tip end of his head—possibly by means of a viscid spot. The mouth is almost vertical, but soon becomes terminal. In two weeks time many sharp teeth make their appearance on the lower jaw. All this while the young fry is so transparent that all his inside affairs and private workings can be as easily observed as one can see a gardener at work inside his greenhouse. The primitive backbone with its developing rays, later to become ribs and spines, the heart pulsating at the rate of 108 beats to the minute, even the corpuscles of the blood flowing along the channels of the arteries, can be plainly seen. The eyes are the biggest and most conspicuous organs because of their dark color and take up about one third the size of the whole head. They are moved rapidly in the sockets together like the wheels of an automobile. Before the fishes hatch, there are a few black, star-shaped or moss-shaped chromatophores,

or color spots on the embryo. Later, small, orange-colored ones appear, and then yellow ones, so that by the time the fish is a week old he is almost golden in color and quite a pretty little fellow. From this time on, as soon as the yolk is all absorbed and the mouth parts are well developed, the little fellows swim about freely amongst the vegetation and find their own food in the minute forms of life with which all water vegetation and debris teems and we may assume that their voracity and their rapacity also grow apace.

Shallow pools that have clear water all the year through, even though they may be choked with vegetation and covered with floating plants during the summer, are likely to shelter these interesting little fishes. At least, such places are worth a careful search for the five-spined stickleback, and if one fails to find them one will be rewarded with a host of other interesting forms of life which abide here in a teeming world all their own.

EARLIEST ALCHEMY

"Let Art learn so much alchemy that it tinctures all metals in gold."
—"Roman de la Rose," Jean de Meung (1277).

By Professor ARTHUR JOHN HOPKINS

Introduction

(a) *The Popular Idea of Alchemy*

OUR conception of the alchemist is pictured for us in English literature by such writings as Chaucer's "Yeoman's Tale" and Ben Johnson's "The Alchemist," in which there is portrayed a man of doubtful character working in mysterious surroundings, so characteristic of the Middle Ages, claiming to have received from some wonder-worker of a still darker age a small portion of that impregnating powder known as the philosopher's stone, by which crude metals could be transmuted into silver or even into gold. He delighted to emerge from his dark cellar, from among his furnaces and alembics, to make dupes of princes or fathers in holy orders. We have here a perhaps slightly exaggerated but essentially true picture of the conditions which obtained in the dark ages of "pseudo-alchemy," from the thirteenth to the seventeenth century.

But the story of real alchemy has never yet been told. The picture given above, if told in present days, would be called a somewhat journalistic exploitation of a period which may be named the decline and fall of the ancient art of alchemy. Even in the Middle Ages, alchemy was very old. Its beginning was far back in the first century of our era. Its birthplace was in the Greek city of Alexandria in Egypt. Its derivation was still more ancient, for its sources are to be found in the philosophy of ancient Greece and in the mystic rites of Chaldea and Assyria.

The present paper has to do with ancient alchemy, or alchemy proper, and attempts to apply the modern research of Berthelot (1885–1891)[1] to the formulation of an entirely new conception of the activities of these earliest chemists.[2]

[1] "Les Origines de l'Alchimie," 1885. Collection des anciens Alchimistes Grecs (3 vols.), 1888.

"Introduction à l'étude de la chimie des Anciens et du Moyen Age," 1889.

"La Chimie au Moyen Age" (3 vols.), 1893.

[2] This theory was foreshadowed in 1902 by a critical study of the recipes of "The Leyden Papyrus," v. Hopkins, Ch. N. 83, p. 49, "Bronzing Methods in The Alchemistic Leyden Papyri."

(*b*) *The Thesis*

The object of this paper is to prove:

(1) That the fundamental art—the art which led up to alchemy—was the dyeing of fabrics, especially with Tyrian purple.

(2) That by this fundamental art was absorbed the art of what we would call bronzing, but what the Egyptian artisans called the tincturing or baptizing of metals.

(3) That there was a close connection between these two decorative color-processes.

(4) That metals were identified by their original colors, but more surely by their bronzes.

(5) That this last conception was upheld by Greek philosophy which was invoked in support of the newer engrafted alchemistic philosophy.

(6) That the transmutation claimed and attained by the Egyptians was essentially a color-transmutation, an artistic interpretation of laboratory experiments. To this transmutation was allied the transmigration of souls of the the Egyptian religion.

(7) That the conception of the philosopher's stone is in accord with this interpretation.

1. The Sources

The earliest known alchemistic document is the Leyden papyrus—a small portion of papyrus V and the whole of papyrus X. Somewhat posterior to this come the Greek writings of "Democritus," Zosimos and Synesios of the period from the second to the fourth century A.D.

The material found in the papyri consists of workshop recipes,[3] mostly for the production of colors on metals, though there are a few for the preparation of the purple dye from seashells and for the use of this dye in producing colored goods. Alchemy fell by order of the Roman emperor, Diocletian, in the year 290,[4] so that we find a gradual change in the character of the commentaries following the recipes of the Leyden papyrus. The pseudo-Democritus presents recipes enclosed in philosophical discussion while Zosimos and Synesios enshroud their guarded statements with double meanings more difficult to understand.

[3] v. "Collection des Anciens Alchimistes Grecs," Vol. I., p. 28.

[4] "Les Origines," p. 72, note 3. "In order that they might not become rich by that art and to take from them the source of riches which permitted them to revolt against the Romans."

2. The Conditions

There is internal evidence that the dyeing of fabrics was carried on in the temple-workshops of Egypt by the priests, the methods and recipes of this art being kept a trade-secret from the common people.[5] It is well known that the art of dyeing had reached a perfection in Egypt nearly equal to that of modern times; also, that two colors were held in great esteem—the purple of royalty, and black, which was the national color, sacred to the god Anubis.[6]

That the art of bronzing was practised in the same temple-shop is attested by the juxtaposition of the recipes for dyeing and the recipes for bronzing in the Leyden papyrus; also by the fact that the mordants used in dyeing were the first reagents employed upon the metals; again, by the fact that the terms used in the art of dyeing were transferred with a similar but different meaning to the bench of the bronzer.[7]

3. Recorded Processes

In the dyeing of cloth, the first process is cleansing and bleaching. The white fabric is then either dyed with a direct color or more often dipped into a mordant bath and then into the dye. These two processes—the direct and the mordant—produce different colors or shades, the second of which the dyer ascribes to the influence of the mordant. The latter, as the necessary intermediary for the production of some valued color, became important to the Egyptian dyer—to a higher degree than to the modern workman, as is explained below.

The colors available for use in decoration of the robes and temples, the trappings of the dead, the mummy cases and ceremonial insignia were limited to a few organic dyes and to the brighter metals, silver and gold. Gold thread was intermeshed with purple fabric in particularly costly robes. Substitution of gold-colored or silver-colored alloys was also practised. It was then found, probably by accident, that certain base metals, when dipped like the white cloth into the mordant-bath,

[5] "Les Origines," pp. 22–25, 185, 250.

[6] Pliny, "Hist. Nat.," XXXIII, 466 (Bohn translation); Collection, Vol. I., p. 69.

[7] Zosimos: Collection, Vol. III., III., 16, 12 (p. 164): "Add some sulphur-water and digest as one does for purple. One must proceed in this transformation, as one does with the product of the sea when this is changed into true purple."

Pelagius: Collection, Vol. III., IV., 1, 9 (p. 259): "You should notice besides that gold or silver simply spread like a superficial paint does not overcome iron or copper. These metals must first be treated with mordants."

acquired thereby, on standing or heating, a new color or shade, sometimes suggesting silver or gold. A white alloy, like the white cloth, thus obtained its color from the mordant.

It is perfectly natural, therefore, that the production of color on cloth and the production of color on metals, in both of which processes the same reagents were used, should have been carried on in the same workshops and that the recipes for producing these respective color-effects should be found in the same papyrus, side by side.[8]

It was shown by the author many years ago[9] that it was possible, by placing in parallel some of the most ancient recipes with recipes taken from a modern book on the coloring of metals, to judge what colors would be obtained, provided the metal to be bronzed were also known. Fortunately the modern reagents are nearly identical with those indicated in the ancient recipes and in these recipes are also described fairly well the composition of the metal or alloy to be bronzed.

What colors then are actually produced under these circumstances in the Egyptian process and also in the modern shop? The answer to this question gives us what seems to be unquestionably the key to alchemistic theory. The bronze most frequently obtained upon silver was black, the national color; and upon gold and gold alloys was that same purple color which was prized so highly for the dyeing of fabrics.

4. The Interpretation

It is difficult, with our modern ideas, to place ourselves in the same mental attitude as the ancient alchemist in order to get his interpretation of these results. We are compelled to remember that his object was to produce color-effects; that he was an artist interested primarily in color. To him the material was of little account.[10] He was in the same position as the modern artist, mixing his colors on his palette, knowing little of the composition of his "reds" and "browns" except the trade name. It would therefore be natural for the ancient Egyptian, interested only in the color-result, to identify silver as the metal upon which a black bronze could be produced; and gold as the material, *par excellence,* upon which it was possible to produce a purple bronze. Moreover, any metal or

[8] Collection, Vol. I., p. 22; "Chimie au Moyen Age," Vol. I., p. 24. Alchemy was known up to the seventh century as "the sacred art" (θεία καὶ ἱερὰ) because it had been practised by the priests, in the Greek temples of Egypt, where other color-processes originated.

[9] In 1902, Hopkins, loc. cit.

[10] v. "Les Origines," p. 281.

alloy upon which a black bronze could be produced would be looked upon as silver-like or simply "silver"; and any metal upon which a purple bronze could be produced was "gold." Those were the days when single metals were uncommon and were not accorded the virtue of an identity. Alloys were most common. Asem or electrum[11] was an alloy, well known, consisting usually of silver and gold. Upon it could be produced either of the favorite colors. By adding an excess of silver or gold to asem, the alloy could be made to acquire more of the properties of either metal, including the property of acquiring a distinctive color by treatment with definite salts. An alloy of copper and tin, like our "bell metal," was white, like silver,[12] and the black bronze could be produced upon it. It was "silver." If to it a little gold were added, the purple bronze could be produced upon its surface. It was "gold." The production of these beautiful and decorative colors became a new industry, probably highly remunerative.

But as time went on, it became clear that the base metals, like copper and tin, could be "improved"—could be transmuted into silver and gold as far as color-production was concerned. The capacity for taking the purple bronze (Ἰωσισ) was the measure of gold.[13]

It was common alchemistic practise to add to such alloys a minute portion of gold. Upon such alloys there was probably produced a higher color—a purple, to be sure, but iridescent. The gold in such alloys was looked upon as a ferment,[14] changing and improving the quality of the whole mass. In the elements of Empedocles, the sequence was from the lowest to the highest: earth, water, air, fire. Following this order, the alchemists had the base metals, earthy; the fusible metals (like tin and mercury) having the property of liquidity; the bright or "noble" metals (gold and silver) remaining clear like air; and the bronzes of a higher spiritual nature, playing like fire on the surfaces of the metals. Between the base metals, such as lead and copper, and the noble metals came tin, and later mercury, considered stages of transmutation.[15] But a little pure gold added to a base alloy, no matter how much, improved its quality and raised it in the rank of metals, just as we some-

[11] Hopkins, *loc. cit.;* Collection, Vol. I., p. 62; also, p. 28, note 3, and p. 31, note 1; "Les Origines," p. 90.

[12] v. Recipe 14 of Leyden Papyrus (Collection, Vol. I., p. 31).

[13] Hopkins, *loc. cit.;* "Les Origines," p. 242; Collection, Vol. I., p. 13; Vol. III., p. 214 (3); p. 219 (5).

[14] Hopkins, *loc. cit.;* "Les Origines," p. 53; Collection, Vol. III., p. 248.

[15] v. "Les Origines," p. 230–231.

times speak of a drop of "infinite goodness" purifying a mass of evil so that its sin shall count for naught.

5. The Philosopher's Stone

Just as a little gold could act as a ferment, so the purple bronze, higher than gold, the spirit of gold, free from "base" or earthy entanglements, could be conceived as having infinite power. Certain references and recipes seem to agree in pointing to a bronze, higher than even the purple bronze in purity, not the spirit of gold, but the "spirit of metallicity," possibly to be identified with the fleeting iridescent purple, as the infinitely powerful tincturing and transmuting agent—"the stone which is not a stone,"[16] etc., the ἰός, or virus, the sperm, the element creative for metals.

Roger Bacon (thirteenth century) does not hesitate to say that the philosopher's stone was able to transform a million times its own weight of base metal into gold.[17]

After their expulsion from Egypt, the alchemists claimed that their predecessors had always been disciples of Plato and Aristotle and that it was from Egypt that these philosophers had obtained the elements of their philosophy. From this the alchemists claimed the right to be called philosophers, "The New Commentators of Aristotle and Plato."[18] This accounts for the first term in the expression the philosopher's stone.

Of the second term, Philalethes says:

It is called a stone not because it is like a stone but only because by virtue of its fixed nature it resists the action of fire as successfully as any stone. In species, it is gold, more pure than the purest . . . but its appearance is that of a fine powder . . . in potency a most penetrative spirit . . . easily capable of penetrating a plate of metal.

Raymund Lully exclaims:

If the sea were of mercury, I would transmute it to gold (Mare tingerem, si mercurius esset).

6. Pseudo-Alchemy

Escaping from Egypt, the alchemists fled, some across northern Africa, finally reaching Spain during the Moorish invasion in the eighth century; some going to the East, through Syria, Mesopotamia, Arabia and Persia, joining hands with

[16] v. "Les Origines," pp. 181–182.

[17] "History of Chemistry," E. von Meyer (Trans. McGowan, 1891), p. 43.

[18] "Les Origines," p. 4.

medicine, which came from India, and finally entering Europe through Constantinople. These refugees brought with them mostly a body of traditions and some manuscripts. After spreading to western Europe, the downtrodden alchemy finally burst into prominence in the thirteenth century.

Unfortunately, the world had advanced. Metals had already claimed for themselves identity and certain unchanging properties such as are familiar to the modern analyst. Alchemists of the thirteenth century like "Albertus Magnus," "Geber," Roger Bacon, "Raymundus Lullus" and Arnaldus Villanovanus, reading the old manuscripts, believed them, without sensing the Egyptian interpretation. They believed that silver could be changed into gold—into real gold in the modern sense. They believed in and ascribed marvellous properties to the philosopher's stone or "Ancient Stone of the Wise Men." Many claimed to be adepts and to be possessed of a small portion of this stone.

It is strange, but fortunate for us, that many of their writings confirm the argument of this paper. For, though they had no conception of the rôle of color in the original alchemistic theory, they quote the ancient alchemistic writings, extolling the wonders of the color-changes just as did Zosimos, Synesios and Olympiodor—the black, white, red, yellow and purple.

Many of their terms are taken directly from the Egyptian workshops. The metal is dipped, baptized (Βαπτίζω) in the bath. It became tinted (tingere) with the color. The word tincture has come down to us in the present-day medicine, as well as the expression "spirit of wine" and the temper of metals. To temper a metal in Egypt meant to bronze it. (This accounts for the recrudescence of the discussion as to whether the ancient practise of tempering copper is not a lost art.) The expressions base and noble metals, hermetic seal, etc., all attest the fact that the pseudo-alchemist of the thirteenth to the seventeenth centuries had in his possession manuscripts of the ancient alchemists—probably some which can not now be found—from which he quoted freely to his astonished audience, the meaning of which he failed completely to understand.

7. The History of Alchemy

It is seen, therefore, that alchemy began in the Greek city of Alexandria in Egypt among a color-loving people, as a simple art of coloring metals, founded upon the discovery that the same reagents that had been used in dyeing would produce

surface-colors on the metals. Greek theories of matter and the Egyptian religious views conspired to uphold the theory that the essential thing was color—not the changing material or body of the metal[19]—so that a change of color was transmutation. Greek theory and the teachings of all kinds of theology supported the idea that each metal had a body, a soul and a spirit; that the spirit was the essential thing, overlying and overcoming the crudeness of the body. Metals were graded in order of perfection. There were base metals and noble metals. The noble metals partook more of the spiritual and could, therefore, be used to perfect the base metals. Moreover, the color was the real spirit, difficult of attainment and hard to keep. As gold improved the lower metals, so the spirit of gold, the ἰός, was identified with the spirit of metallicity—the penetrative tincture—which could tint all metals into gold—the philosopher's stone.

Centuries rolled by. The artistic yearning for color was nearly gone and the methods of recognizing pure metals were much advanced, when in the thirteenth century a false alchemy arose, which claimed on the authority of the ancient writings to be able, by the philosopher's stone, to change lead and copper into silver and gold.

The simple art of the Egyptians had been harmless. Its mission was to feed the color-hungry people of Egypt and it had been eminently successful. Pseudo-alchemy was the teaching of men glorifying in a rapture of self-deceit; later of charlatans who deceived others knowingly. Pseudo-alchemy never succeeded in its pretensions. It succeeded only in holding back scientific progress for some centuries and in bringing into disfavor the fair name of science. This alchemy, so-called, lingered on under the teachings of iatro-chemistry and the impetus of the phlogiston theory until its pretensions were finally crushed by the impressive experiments of Lavoisier, in the latter part of the eighteenth century.

Conclusion

This paper presents a new theory of the origin of alchemy. The theory is supported (1) by internal evidence, drawn from the original alchemistic recipes and the earliest Egyptian manuscripts of about the third century A.D.; (2) by the teachings of the alchemists themselves and (3) by the language and experiments of the pseudo-alchemists of the Middle Ages.

[19] v. "Les Origines," p. 75, p. 281; Collection, Vol. III., 6–10, p. 127.

THE ENGINEERING PROFESSION FIFTY YEARS HENCE[1]

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Prelude

ENGINEERING, in one sense the youngest and in another the oldest of all the learned professions, has attained its importance and high standing mainly during the last half-century. It is universally acknowledged to be the profession of progress; and all thinking people concede that without it the advancement of the world would come immediately to a standstill, and even the maintenance of modern civilization would be impracticable. Just imagine what civilization would be without the steam-engine, railroads, steamboats, bridges, the telegraph, the telephone, water-works, sewerage, the typewriter, electrical machinery, the gas-engine, the automobile, mining, metallurgy, applied chemistry, water-power, steel buildings, reinforced-concrete constructions, agricultural machinery and irrigation! All these activities and many others too numerous to mention come within the province of the engineer, and their development has been his task. The importance of the engineer in the community was emphasized in polished language as follows in an editorial of the *Canadian Engineer* for October 18, 1917:

[1] Before starting to prepare this article, the author wrote to a number of his good friends in the various branches of engineering, and propounded to them the following questions:

"*A.* What deficiencies, shortcomings, or defects do you note in our profession in general, and how would you suggest correcting them?

"*B.* In regard to your own specialty, what improvements would you desire, and how do you think they may be effected?

"*C.* In your special line of work, have there been any fundamental novelties or drastic innovations suggested which are either practically feasible or even possible of future adoption? If so, please give a brief description of them; or, if they have been already described in print, tell me where I can find the information."

A few of the responses received to these questions furnished data of considerable value to the speaker in preparing this manuscript; and he takes this opportunity heartily to thank, individually and collectively, the gentlemen who so generously responded to his appeal for aid. It is deemed inadvisable to enumerate their names, especially in view of the fact that their contributions have been utilized mainly as suggestions for development rather than for direct quotation. This arrangement was understood at the outset by all concerned.

Every industry depends directly upon the engineer. There are few points of life where his work has not effected big alterations. Tolerant

he must be to human weakness; efficient he must be, for in few other fields of effort is the elimination of the unfit more rigorously practised. His training is applied science, and his practise demands large common-sense.

The engineer is one of the pivots of modern civilization; therefore he should be more in evidence as a public man. He is well fitted to carry forward the lessons of practical experience in the realm of national affairs.

In war as well as in peace the engineer stands preeminent, as is evidenced in the present struggle, by such prominent military men as Joffre, Kitchener, Cadorna and von Ludendorf.

The world could manage to dispense with lawyers and clergymen, and, possibly, even with physicians, but it would be impracticable to get along without engineers. Very few people, however, have looked at the matter in this light; and the engineer, in consequence, has not yet received from the public the consideration which is his due, nor the pecuniary compensation which his services merit.

The fundamental reason for this undesirable state of affairs is, undoubtedly, the newness of engineering as a learned profession, but it must be confessed that much of the blame therefor lies with the engineers themselves. They have been so intent on their own individual activities that they have not fully organized for their protection as a class; and although the engineering societies, both large and small, have done great work and have accomplished much towards the betterment of conditions, their effectiveness is far from being ideal. The larger societies are too cumbersome to accomplish desired reforms in any reasonable length of time, and the smaller societies generally have not in their ranks enough men of prominence.

Recognizing this, some years ago a few engineers in independent practise founded the American Institute of Consulting Engineers. It is proving, in certain lines, to be a most excellent organization; but its field of usefulness is too limited. Its objects are in a certain sense selfish; and its constitution excludes all engineers who are engaged in contracting and most of those who are in the employ of manufacturing or contracting companies.

Some eight years ago a few engineers came to the conclusion that the profession needs at its head a comparatively small and select body of engineers chosen from the leaders in every branch of activity and from all parts of the country, in order to undertake those duties which the existing societies neglect. They, consequently, endeavored to organize an "American Academy of Engineers" on the broadest and most altruistic

lines; but they encountered many obstacles which delayed for a long time the accomplishment of their purpose. The principal stumbling block was the difficulty in organizing without subjecting the charter members to the accusation of being self-appointed. It was claimed, and very properly, that the making of such an accusation would militate seriously at first against the effectiveness of the academy, and might even be the means of ultimately preventing its successful establishment.

Great undertakings are apt to move slowly; and such was the case in this endeavor, for it was not until the end of 1916 that a truly impersonal means was evolved for the selection of the nucleus of the Academy. The *modus operandi* finally adopted was as follows:

The Honorable William C. Redfield, secretary of commerce, who for several years had taken a deep interest in the undertaking, and who had been requested in writing by many prominent engineers from all parts of the United States to take the initial step towards the formation of the academy, appointed Major-General George W. Goethals as the first member, and instructed him to select nine others from among the most prominent engineers in all branches of the profession, limiting his choice by the inclusion of at least one past-president from each of five national engineering societies which he named. General Goethals in complying with his instructions went a step farther by selecting one past-president from each of eight national engineering societies, thus covering practically all lines of the profession, and two at large, dropping out himself on the plea that he objected to accepting a government appointment to such an organization. The ten engineers thus chosen met at once in order to select the other forty engineers so as to form the nucleus of the academy and then apply to Congress for a national charter, all in accordance with the program of Secretary Redfield, as indicated in his letter of instructions to General Goethals.

At the first meeting, which was held in New York City, it was unanimously decided that General Goethals should be the first one chosen, and that he should be requested to aid in the selection of the remaining thirty-nine, to which arrangement he subsequently agreed. The method employed was to let each of the eleven members nominate as many suitable candidates as he might desire, and from these, by a process of elimination, to choose the number required. Over one hundred names were proposed, and approximate percentage-limitations for the various groups of engineers were agreed upon. A number of meetings, extending over several weeks, were found necessary.

Each candidate's fitness was thoroughly discussed, and his proposer was required to state in writing the said candidate's professional record and the reasons why he was believed to be specially eligible. A consideration of geographical location was deemed requisite; and for that and other good reasons it was found necessary to exclude temporarily a number of engineers who are in every way eligible. Not one of the fifty gentlemen thus chosen as charter members failed to accept his election.

By direction of Secretary Redfield, the solicitors of the Department of Commerce prepared the draft of a bill for the incorporation of the academy; and this bill was introduced in both the Senate and the House of Representatives. It was passed by the Senate during the late special session of the Congress; but the judiciary committee of the House postponed its consideration until the next regular session. Arrangements are being made for the said judiciary committee to take up the consideration of the bill in the immediate future.

Some opposition has been raised by a few engineers to the granting of a national charter to the academy, the cause apparently being an absolutely unfounded fear that the new organization will usurp some of the functions of the existing national technical societies, but mainly because the true intent of the academy is not generally known or understood.

The fundamental reason why it will eventually succeed in accomplishing many important desiderata for the profession where the large national technical societies have failed is that there are in each group or line of engineers a few individuals who have a deep love for the profession, and who are ever ready to subordinate to its welfare their own personal interests —men who generously spend time, effort and money in giving to others by their writings the benefit of their knowledge, accumulated through many years of hard work—men, too, who are prominent in research, in originality, in organization, in altruism and in energy. If all, or a large proportion, of such men from every line of technics were combined into an academy, having a membership limited to two hundred, is it not evident that the amount of good which they could accomplish would be enormous and that the results of their efforts would be far-reaching and invaluable? It is mainly of such men that the American Academy of Engineers is and will be composed. The fifty names of the charter members are a proof of the correctness of this assertion; but additional evidence is given by the following quotations from the temporarily adopted Constitution and By-Laws:

Professional Objects.—These shall be: To dignify and to exalt the profession of engineer in the broad sense, and to place it upon the highest plane amongst the liberal professions; to bring the different branches of the engineering profession into closer touch and harmony with each other; to bring American and foreign engineers into closer relations with each other; and to secure for the engineering profession as a whole the recognition that is commensurate with the importance of its services to the world.

National and Civic Objects.—These shall be: To render to the government of the United States of America or to any commonwealth of the nation, when so requested, service in the field of engineering, industrial technology, and applied science; to cooperate, in rendering such service, or for any purpose involving the welfare and interests of the country, and to subserve the same, with American national academies, institutes, societies, or bodies interested in pure and applied science, technology, and engineering.

Ways and Means.—The academy will strive to accomplish these objects by all proper, honorable, and legitimate ways and means; by fostering, stimulating, and encouraging the growth and development of the highest professional spirit, ideals, and ethics uniformly in all branches of engineering; by promoting a better understanding and sympathy between these different branches; by advocating more homogeneous and consistent rules and precepts for their guidance in their relations with each other and with the rest of the world; by working for general cooperation and solidarity; by fostering an *esprit de corps* in the profession as a whole; by doing all in its power to elevate the standards and promote the interests of the profession; and by urging its claims, or those of its more distinguished and eminent votaries to due and proper consideration for public or private honor or recognition. . . .

Members.—Members shall consist of properly qualified engineers having eminence or distinction in one or more branches of enginering, by reason of their professional attainments, learning, or experience, and of their contributions to the progress and advance of their branch or branches of engineering or of the engineering profession as a whole.

The qualifications of a candidate for member shall include the following requirements:

(*a*) He must be a citizen of the United States of America.

(*b*) He must be at least forty years of age.

(*c*) He must be a member, in good standing, of the highest grade, in at least one national engineering or technical society in the United States of America.

(*d*) He must have practised or else taught engineering, or some cognate branch of technology (such as chemistry), continuously for a period of not less than fifteen years, and he must be still engaged actively in practising or teaching or both; or else, in lieu thereof, he must have been identified with work of importance, either by reason of its magnitude or else because of its novel or special character; and it must be shown that he has made a satisfactory record and has obtained a good standing in his branch of the profession through his technical work.

(In the case of a teacher of engineering or of technology, the publication of original books relative to his branch or branches of the profession shall be taken as the equivalent of engineering work.)

(*e*) He must have a personal as well as a professional record, reputation, and standing, entitling him to the highest consideration as a pro-

fessional gentleman who is devoted to the progress and advance of the engineering profession and who is interested in promoting the welfare and sustaining the dignity of that profession.

Other qualifications, constituting criteria of eligibility to membership, are prescribed in the By-Laws. . . .

Eligibility.—The additional qualifications, referred to in Article II of the Constitution as constituting criteria of eligibility of a candidate for member of the American Academy of Engineers, shall be such as indicate the general education, the technical training, and the professional experience and record of the candidate. They shall include the following requirements:

(*f*) He must have a degree from a university or technical school of recognized standing.

(*g*) He must have a reading knowledge of at least one European language, or else of Esperanto, besides the English language.

(*h*) He must have been in responsible charge of engineering or technical work or design for a period of not less than five years. If teaching, he must have been in charge of a department in a school of recognized standing for a period of not less than ten years.

(In the case of candidates who have taught and practised at different portions of their careers, two years of teaching shall be considered the equivalent of one year of engineering practise.)

(*i*) He must be the author of at least one important original publication on some subject or topic related to at least one branch of engineering.

In general, the intellectual status of the candidate, and the personal traits or qualities making him a credit to the profession of engineering, and, especially, his zeal and devotion to that profession, shall be the paramount considerations in determining his fitness. His financial status shall be of no consideration whatever.

Waivers.—Any of the foregoing requirements may be waived in any particular case in behalf of a candidate otherwise very desirable; but the said waiver shall be only by the unanimous vote of the Board of Directors. . . .

Scope and Program.—The academy shall avoid encroaching upon the scope and program of any of the engineering and technical societies representing special branches of the engineering profession, and it shall limit and confine its activity to questions of such nature and character as are likely to interest and to affect the profession as a whole. These questions may include ethics, relations with other professions, matters of general professional policy or expediency, questions of political or commercial economy involving engineering, national and international engineering topics, etc.; and the program shall specifically exclude engineering and professional papers of the types usually presented before the various engineering and technical societies.

Communications from non-members, when introduced by a sponsor member of any class, may be presented and published with the approval of the publication committee.

Annual Publication.—This shall contain the proceedings of the meetings, and the reports, including discussions, of papers and communications presented before the academy and approved by the publication committee for publication.

A copy of the annual publication shall be sent gratis to every member, emeritus member, and honorary member of the academy; to every important national engineering society in the world; to the governor of

each state and territory, to the library of every university and technical school of recognized standing in the United States, and to the libraries of certain foreign institutions of learning. The list of institutions and individuals to whom copies are to be sent gratis shall be subject to the approval of the publication committee. Copies shall also be available at a reasonable price to any person desiring the same, if ordered before publication, or otherwise if there be copies available.

An apology is due for the length of these quotations from the constitution and by-laws; but the purpose the writer has in mind in making them could not well be accomplished by shortening them in any way. These extracts show not only that the American Academy of Engineers is to be a technical and scientific society of the highest possible order, but also that its aim is to supplement—not to supplant—the other national technical societies.

Through its honorary members, who are citizens of foreign countries, American engineers will be brought in contact with their professional brethren abroad; and a large amount of business for our country will certainly result from this connection—business which otherwise would naturally go to other countries than ours.

It seems to the writer that no truly broad-gauge man in any walk of life can oppose the incorporation of the American Academy of Engineers as a national organization; for, unless it were given governmental recognition, it would not be regarded by people in general as the national association of engineers chosen from every line of technics, nor as the select body of practitioners which it is intended to be; and, therefore, its capacity for doing good would be most effectually curtailed. Again, it would not be properly recognized, at least for many years to come, by foreign governments and foreign technical and scientific societies, nor could it act, in the manner intended, as a court of last appeal for American engineers in all lines of the profession. Moreover, the national and the state governments would not feel that they have the right to call upon it for advice and assistance to be given gratis, unless it were a national body; nor could it properly take the initiative in many important movements affecting the welfare of the commonwealth. For these reasons, and for other important ones too numerous to state, it is to be hoped that nothing will prevent the granting of a national charter to the American Academy of Engineers at the present session of Congress.

The principal existing "deficiencies, shortcomings, or defects" in the engineering profession in general, as indicated by a consensus of the answers to questions *A* and *B* of the circular

letter which, as previously indicated, the writer sent to some of his technical friends before starting to prepare this lecture, are, in the indicated order of importance, as follows:

A. Lack of appreciation of the profession by the public.

B. Deficiency in general education on the part of most engineers.

C. Lack of culture.

D. Failure of the technical schools to provide proper instruction in the English language.

E. Failure of the technical schools to give a broad, general education.

F. Uncertainty as to the definition of the term "engineer" and exactly the class of men which it should include.

G. Too small compensation for engineers.

H. The fact that engineering is too largely a profession of regularly employed men; or, as it has been rather pithily but inelegantly stated, that "too many engineers wear the brass collar."

I. Need for a license system—federal, but not state.

J. Lack of publicity concerning engineering achievements and general technical news and interests.

K. A tendency among some engineers for one man to appropriate another's inventions or ideas.

L. Undue criticism of one engineer's work by a brother engineer.

M. Failure on the part of engineers to recognize what the profession really is.

N. Need for a clearer appreciation by engineers of the rôle they are called upon to take.

O. Lack of loyalty to the profession and to the members thereof.

P. Giving of advice and doing of preliminary work gratis.

Q. Deficiency in accurate thinking.

R. Lack of accuracy in doing work.

S. Carelessness and slovenliness.

T. Lack of address, and inability to speak well.

U. Inability to write well.

V. Lack of initiative in public affairs.

W. Improper methods of instruction in technical schools.

X. Ignoring of individuality in students by teachers of technics.

Y. Lack of direct connection between research and engineering practise.

Z. A tendency to usurp the title of consulting engineer by those who are not equipped to bear it.

a. Inability of many engineers to handle men.

b. Need in this country for a better patent system.

c. Opposition in America to the trying out of new devices and processes, and waiting instead for Europeans to make the trial.

d. Favoritism instead of merit as the reason for promotion of employees in large companies.

e. Need for a fixed minimum-fee basis for engineers' compensation.

f. Need for greater standardization of engineering practise.

g. Need for "abbreviated engineering data."

h. The study of one branch of engineering at school and subsequent practise in another branch.

The preceding is a rather appalling list of the alleged "deficiencies, shortcomings, or defects" that exist in the engineer-

ing profession; but it must be remembered that it represents the combined complaints of more than twenty engineers, representing all the leading branches thereof, each individual, of course, contributing his pet grouch; nevertheless a careful study of the list will convince one that each allegation is fairly well founded, and that the existence of many of them is beyond dispute. Remember, too, that these deficiencies apply to the profession as a whole, including the rank and file, and by no means to all of its members.

A study of the list will show that most of the deficiencies are of such a character that they are not corrigible by any of the existing technical societies; but they certainly are by an organization of the peculiar character and scope of the American Academy of Engineers.

Dr. C. O. Mailloux in his presidential address to the American Institute of Electrical Engineers spoke as follows:

> We must show to the rest of the world that engineers are, by education, training, and experience, as well qualified as any professional class, to discuss and deal with public questions and problems, and that in the case of technical questions we are better qualified than are the other classes.
>
> We not only fail in our duty to our professional class, but we also fall short of doing our full duty to the community by remaining silent in the social and civil background, and by hiding the important light which we are most able to shed on many public matters by virtue of our scientific and technical training.

It is a certainty that much remains to be done to put our profession upon the high plane where its importance to humanity entitles it to stand, and that reforms can be instituted only by concerted effort. The large national technical societies have gotten into ruts, and it is hard to jog them out—besides, the unwieldiness inherent in their great bulk militates strongly against a combination of all their efforts. It is far better to choose a limited number of the most live, energetic, earnest and altruistic members of each group and form them into a new organization which will act in concert and harmony with all the other national technical societies, as has been done in the case of the American Academy of Engineers. The new society could take the initiative and then apportion most of the work among the other organizations, reserving for itself the unusual or general tasks which no one of the other societies is specially fitted to handle. If the academy, after having been granted by Congress a national charter, were properly officered and systematically operated, there would be, ere many years, a wonderful improvement in the general status of the engineering profes-

sion; and most of the evils complained of would be fairly well corrected. Perfection, of course, can never be attained, but it is practicable to approach it by an asymptotic curve.

The present is the psychological time for bringing the engineering profession into its own; because never before in history has mankind been so dependent upon the engineer. The existing war is essentially a war of engineers; for it is they who are manufacturing the guns, ammunition, vessels, motors, and the other paraphernalia requisite for carrying on the struggle, and who are attending to the transportation of men, munitions, food, and all other supplies by both land and sea, besides doing their fair share of the fighting. The public is now beginning to recognize the truth of the sayings that, "when something of importance has to be done, it is necessary to call in the engineer," and that "engineers are preeminently the producers of results."

Concerning the relative importance of the engineer's work in the world to-day, it may be stated, without any reservation, that it is he who is responsible for our present civilization in the material sense and even, possibly, also in the mental sense. It is truly an engineer's age. Countries are built up and torn down by the engineer. He is a creator; he brings together elemental forces and gives them direction. He takes the natural things from the earth and makes of them the complex things of life. If his work were to cease, the world would retrograde to uncivilization as we understand the word to-day.

The speaker has stated that "the present is the psychological time for bringing the engineering profession into its own," but he wishes to add to this another claim, viz., that it is also the psychological time for our country to secure the trade of Latin-America as well as to prepare for obtaining the lion's share of world-reconstruction after the war. Both of these tasks are work for the engineer, because it is he who first will have to go to those countries in order to spy out the land, determine what works of construction are necessary, and do missionary work for American manufacturers, capitalists, and contractors; and it is a *sine qua non* that the reconstruction mentioned is essentially his *métier*. Such being the case, now is the logical time to improve the engineering profession in America so as to enable its members to render the most effective service possible in these activities of national importance.

Perhaps the most outstanding factor at the present time, bearing upon the future of engineering, is the new standard of values brought about by the war. This is, undoubtedly, the

most widespread and revolutionary change in the history of mankind. Not only have money values varied greatly in a short period of time, but the war, on account of its widespread nature and because of the vital principles affecting the future progress of mankind, for which the Allies are fighting, has brought us face to face with one of the most important stages in the cycle of civilization.

Engineering works are the surest index to the state or degree of civilization to which a nation has arrived; and, owing to the rapid progress and readjustments which will be the outcome of the war, these same works will undergo a more rapid change and growth in a given time than history has yet shown. What may have seemed a colossal engineering work a few years since will become commonplace henceforth. An illustration of this is the growth in the size of steamships. How many times we have heard of huge vessels having been constructed and regarded as the final word in marine architecture! Drydocks have been built to take care of the largest vessel that would ever be constructed, yet in a few years these same docks are found to be totally inadequate to handle anything but that which has come to be considered a vessel of ordinary size. The same remark applies to bridge loadings. Many bridges have been built to take care of all possible future loads, and yet the weights of locomotives and loaded cars have increased so fast that the structures are out of date long before they show any sign of deterioration from the elements. This analogy could be continued indefinitely to apply to actual cases concerning transportation systems, office buildings, canals, water-works, etc.

The increase in requirements or demand seems to be in an ever-augmenting ratio, the curve varying with the periods of business prosperity and depression. In short, engineering works will always meet the demand; and the demand is increasing steadily. It is quite reasonable to imagine the City of New York as having grown to a city of twenty million inhabitants; and when such a change exists, there will be engineering works such as bridges, tunnels, water-works, transportation systems, etc., in which almost inconceivable sums of money have been invested. If there is a compelling need for a structure of unprecedented size, then that structure will be built—the cost is merely a relative matter. Given enough money (and the money will be found, if the need is sufficiently imperative), there is almost no engineering feat that can not be accomplished.

(To be continued)

CHANGES IN FACTORS THROUGH SELECTION

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MOST interesting of all the mutations that are now engaging the attention of students of mutation are those in which genetic factors or genes occur, or appear, whose most obvious action is to enhance or diminish some other more conspicuous character. These genes may be called specific modifiers. They do not differ from ordinary genetic factors in any essential respect, but, since their presence can not be detected, except when other factors are themselves producing some particular effect on the individual, it is convenient to give them a special designation.

For the correct interpretation of the results of selection, it is essential to have some means of finding out whether any effects that are produced are due to specific modifiers or to a change in the principal gene itself. For instance, there are several cases where a mutant character is known to be due to a single Mendelian factor, and selection has caused the character to change in the direction of selection, either plus or minus. Since the character is demonstrably due to a single factor the first conclusion that was drawn was that the change in the character *must* be due to a corresponding change in the factor that produces it. Such a conclusion may be fallacious, however, for the change may be due to the appearance during selection of specific modifying factors, or to their segregation if they were present at the start in a mixed stock. Until suitable tests were made, one interpretation was as valid as the other and without such test the wrong inference might be drawn.

It is obvious that it could never be shown that genetic factors do not change under the influence of selection if each time progress took place the results were ascribed arbitrarily to modifying factors. Conversely those who claim that progress comes about through modifying factors could never hope to establish their view so long as the possibility of the chief factor itself changing and producing the observed effects was open to discussion. But a modern technique has been worked out along

several lines by means of which crucial evidence can be obtained that will make probable or even demonstrate whether the main gene or modifying genes are involved. Let us examine the ways in which a decision may be reached.

1. Starting with a mixed population in which the principal gene and one or more specific modifiers are present (the latter irregularly distributed amongst its members) and breeding in pairs along definite lines, we should expect to find in the first five or six generations that selection in a plus or minus direction would cause a definite change in the direction of selection and that then the process would slow down. This is the result that McDowell obtained when he selected flies for the number of bristles on the thorax, and it is in harmony with the view that modifying factors were present at first, irregularly distributed, and were sorted out by selection. If selection had really caused a principal gene for bristle number to change in the direction of selection it is not apparent why its progress should slow down and cease after a few generations, especially when selected in a minus direction. This argument gives results that are intelligible on the hypothesis that the change is not in the gene itself, but the method is insufficient to disprove that the gene changes; for, it might still be claimed that genes yield more at first to the treatment of selection and less later on.

2. It has been pointed out especially by East that the variability (spread) in the first hybrid generation (F_1) is often characteristically less than in the second (F_2), and this is expected on the theory of multiple factors, because the F_1 individuals are in their hereditary composition more likely to be uniform than the F_2 generation that results from the sorting of all the kinds of factors present in the F_1 generation.

3. The fact that there is less correlation between the "grade" of each F_1 individual and F_2 offspring than there is between each F_2 individual and its offspring (F_3) is expected on the multiple factor hypothesis, because all the differences of the F_1 individuals are not so probably due to genetic differences as are the differences between the F_2 individuals.

These and other correspondences between the expectation for modifying factors and the facts that are known in several cases create a strong presumption in favor of the theory, even though they do not pretend to demonstrate conclusively that modifying factors are present.

4. We may next turn to cases that furnish an actual demonstration that selection has produced its observed results through the isolation of genetic factors. This evidence is furnished by

linkage. Owing to the fact that in several cases linkage of factors is known, it may be possible to identify the presence in individuals of modifying factors when these are linked to visible ones. To run down modifying factors in this way is tedious, and to be entirely successful presupposes that all the great groups of linked genes are known and that within each a considerable number of loci are available. At present *Drosophila* is the only type which fulfills these requirements, and here at least five cases are known where the presence of specific modifiers has been demonstrated in the same way as all other genetic factors are demonstrated. Two examples may be given to show how such a demonstration was possible.

FIG. 1. A female fly (Drosophila melanogaster) from a mutant stock called notch in which the ends of the wings instead of being rounded (see Fig. 3A) are serrated. The factor producing the character is sex linked and dominant. It is also lethal, so that no males with notch appear because the male has but one X-chromosome. In the female, however, with two X's, the lethal effect of the notch gene in one X is counteracted by the normal allelomorph in the other X; but the dominant effect of the gene remains.

The general procedure is as follows: By appropriate matings to be described below, two kinds of individuals are produced that differ from each other in known respects, *i. e.*, in having different combinations of chromosomes. By testing in turn all the possible chromosomal combinations the presence of specific modifiers can be made out with certainty. An example will show in detail how the test is made. There is a dominant character known as notch wing, Fig. 1, whose gene lies in the sex chromosome. The character was found to be very variable in the original stock; a few flies in each generation that carry the factor have normal wings. By means of linkage experiments these normal-appearing notch females can be picked out from the real normals. By selecting such females for several generations the stock was changed to such an extent that more than half of the notch females had normal wings, and the rest had only faint indications of the notch. Females from the selected stock were bred out to males of another stock

in which one of the third chromosomes contained a dominant factor (dichete) by means of which its presence could be identified. It was found that when both of the original third chromosomes were present the selected type of notch occurred, but when a dichete-bearing third chromosome was present the atavistic type of notch was present. The inference was that the modifier was present in the third chromosome and the inference became a demonstration when by means of similar tests for the other chromosome no modifier was found in them. The details of the test for the third chromosome alone are shown in Fig. 2, but the general nature of the test can be understood without need of this somewhat technical diagram.

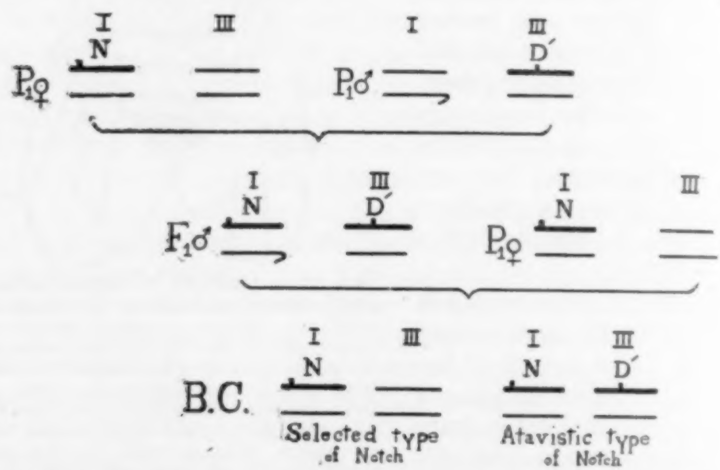


FIG. 2. Diagram to show how a specific modifier was located. The principal gene N for notch wing was carried in the first chromosome, I. A notch female (P_1) was mated to a male (P_1) that had a dominant gene for dichete bristles, D^1, in the third chromosome, III. A dichete son (F_1) was back-crossed to a notch female of stock (P_1). Two kinds of notch daughters are expected (BC), one having the original pair of third chromosomes should be like the original selected stock; the other with one of the original third chromosomes and its mate from the dichete grandfather. This female should be like the original (atavistic) type since the influence of the modifier in the third chromosome is dominated by its normal allelomorph in its mate, the dichete chromosome.

Another experiment made by Sturtevant in a different selection experiment was essentially the same. Only a preliminary statement has been made as yet by Sturtevant, and the following report is, with his permission, based on the complete account in press at present. He made use of a race of *Drosophila* called dichete, Fig. 3, *B*, characterized by fewer thoracic bristles on the average than in the wild type. In the wild fly there are four dorso-central and four scutellar bristles, Fig. 3, *A;* the

former vary from 3 to 6, the latter vary less. In the dichete flies the bristle number for both groups of bristles taken together is from 3 to 7, five being the most common type.

Selected in the plus direction a race was produced with 6 as a mode and with a range from 4 to 8, selected in the minus direction the mode became 4 and the range from 1 to 6. Brothers and sisters were obtained that were alike in the first and in the third chromosomes, but different in the second chromosome. A comparison between them showed that a

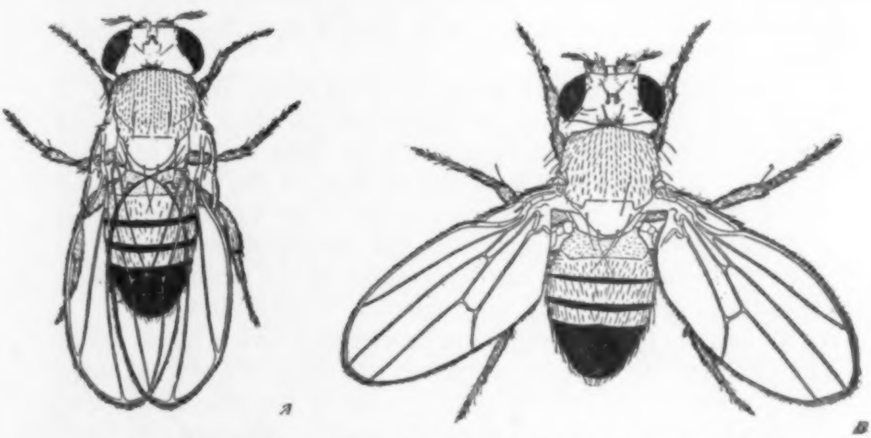


FIG. 3. A NORMAL MALE (Drosophila melanogaster), A, and a dichete male, B, that lacks certain bristles on the thorax. The gene is dominant and not sex-linked, but it is lethal in double dose. Hence all dichete flies (♂ and ♀) are heterozygous for the gene.

modifier was present in the second chromosome. In other words, selection for the number of bristles had changed the number, because a specific modifier for bristle number appeared in the course of the experiment in the second chromosome. Selection had produced its results by isolating a race in which the second chromosome pair contained a modifier.

A third example could be given in which the specific modifier appeared in the same chromosome that carried the principal gene itself. No doubt cases will be found in which two or more specific modifiers are present. Their detection becomes then more difficult but can still be accomplished by the same sort of procedure.

An analysis of this kind brings to bear on the problem really critical evidence. Until equally cogent evidence can be obtained in other cases where it is claimed that mutant genes are modified by selection I do not think that this conclusion can be accepted.

Mutants of Multiple Allelomorphic Genes

Another one of the interesting and important discoveries in recent years has been the demonstration that more than one modification of the same gene may appear. The discovery is important not only because it shows the untenability of a current view that all mutants are due to losses of normal factors, but also because it shows that such mutant factors behave towards each other in the same way as the mutant gene behaves towards its normal gene (its "allelomorph") and consequently makes somewhat probable a view difficult to demonstrate otherwise that the normal gene is itself a gene like the mutant gene.

Multiple allelomorphs have now been found in a number of different forms. In mice the characters for black, yellow, gray with white belly, and house mouse gray form a series of allelomorphs. A mouse may have two of these at the same time but never more. If the genes are carried by the chromosomes and occupy identical locations in the chromosomes we can understand why only two can be present in the same individual, since there are only two chromosomes of each kind.

In rabbits there are three members of a series, black, albino and Himalayan. In corn, Emerson has described several allelomorphs that represent different grades of striping of the seed.

In one of the grasshoppers, *Paratettix,* Nabours has found about 13 allelomorphs affecting the color pattern of the body. It is not certain that this series is due to allelomorphic genes, for the same results would happen if the genes in question were in the same pair of chromosomes and no crossing over takes place. If, however, it turns out that these factors are allelomorphs the case is interesting because the types are found in the wild state.

By far the greatest number of series are in the fruit fly,[1] where their origin is known and where in consequence we are in a position to demonstrate from their mode of origin that they do not necessarily arise in that orderly sequence which their degree of development or expression might lead one to assume. The latter point, as will be shown, has an important bearing on our interpretation of what selection might be expected to do in cases where multiple allelomorphs arise or are present.

So far as the absence hypothesis is concerned, it is evident

[1] There are about 12 groups of multiple allelomorphs. The most extensive one is an octuple modification of the eye color involving white, eosin, cherry, etc.

that if by absence we mean literally that mutant factors are absent genes, there could be but one kind of absence for each normal gene, hence there could not be a series of absences as the hypothesis of multiple allelomorphs assumes. If this is conceded and the hypothesis changed to mean that by absence only some part of a postulated organic molecule, or normal gene, is "lost," then a new point of view emerges. Suppose, for instance, the loss of a CH_2 group might give a new gene, the loss of another CH_2 group another gene, etc. On such an assumption several kinds of genes like several kinds of paraffines might be possible. But on the other hand the taking up of a CH_2 group, or a shift in position of two of the groups, might equally well make a new gene. There is at present no way of determining what kind of alteration produces a new allelomorph, hence the futility of insisting that such alterations must be losses rather than additions or alterations in position of parts of the gene. It need scarcely be added that there are no grounds for assuming that a deficiency rather than any other kind of alteration is the only change that will lead to a lessening of the development of the final product for which these genes are responsible. Fascinating as it might be to draw a parallel between the series of genes and the series of resulting multiple allelomorphs comparable to such series as the sugars or alcohols or paraffines with their corresponding graded differences in physical or chemical properties, such parallels are at present only in the speculative stage.

The demonstration that multiple allelomorphs are modifications of the same locus in the chromosome, rather than cases of closely linked genes, can come only where their origin is known and at present this holds only for Indian corn and for the fruit fly. If each member of such a series has arisen historically from the preceding one in the series by a mutation in a locus closely associated with the locus responsible for the first, they would be expected to give the wild type when crossed; and as the proof of their allelomorphism turns on the failure of members of the series to show the atavistic behavior on crossing, it is necessary, as stated, to know how they arose. This may be made clear by the following illustration:

Let the five circles of Fig. 4, *A*, represent a *nest* of closely linked genes. If a recessive mutation occurs in the first one (line B *a*) and another in the second gene (line B *b*), the two mutants *a* and *b* if crossed should give the atavistic type A, since *a* brings in the normal allelomorph of *b* and *b* that of *a*. If a third mutation should occur in the third gene, it, too, will give the atavistic type if crossed to *a* or to *b*. Similarly for a

mutation in the fourth and in the fifth normal gene. Now this is exactly what does *not* take place when members of an allelomorphic series are crossed—they do not give the wild type, but one or the other mutant type or intermediate characters. Evidently independent mutation in a nest of linked genes will not explain the results if the new genes arise directly each from a different allelomorph.

But suppose, as shown in Fig. 4 (line C) after a mutation had occurred in the first gene a new mutant, *b*, arose from

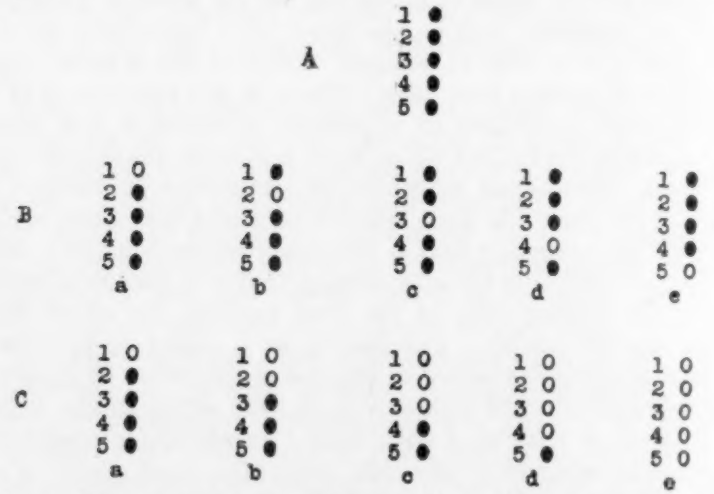


FIG. 4. Diagram of an imaginary "nest" of genes (A). In B the stages are independent mutations. If these stages *a*, *b*, *c*, etc., were crossed, the original type (wild type) of character is expected, since each stage would carry a normal allelomorph of the mutant gene in the other. In C the series of changes is indicated that might occur if *a* gave rise to *b* and *b* to *c*, etc.

a new gene, and from *b* a mutation arose in a third gene *c*, and *c* similarly gave rise to *d;* then *a* crossed to *b* will give *a* (or something intermediate if the heterozygote is an intermediate type). Likewise *c* crossed to *b* will give *b*, or *c* crossed to *a* will give *a*, etc. If mutant allelomorphic genes in a series such as *C a, b, c, d, e,* arise as successive steps, *i. e., Ca* to *Cb* and *Cb* to *Cc*, etc., then the hypothesis of closely linked genes would seem to be a possible interpretation, but if they do not arise in this way but by independent mutations from the wild type (or even from each other but not seriatim), then they must be due to mutations in the same gene; for, to assume that they are not, requires that, when the second mutation took place, both gene *a* and gene *b* mutated at the same time, and that when *c* appeared three genes mutated, when gene *d* appeared; when gene *e* five genes mutated at once, four of them bearing

mutant genes that have already arisen independently. Such an interpretation is excluded, since it is inconceivable, even in a readily mutating form like *Drosophila*, that five mutations could have occurred at the same time in distinct but neighboring loci. As has been stated the evidence from Drosophila shows positively that multiple allelomorphs arise at random.

The other evidence for multiple allelomorphs comes from an observation on Indian corn. Emerson has shown that when a race of corn having red cobs and red seeds is crossed to a race having white cobs and white seeds only the two original combinations appear in the second (F_2) generation, viz., plants with red cobs and red seeds and white cobs and white seeds. It follows that either a single factor determines that both cob and seed are red in one case and white in the other, or if the color of each part is due to a separate factor these must be so closely linked that no "crossing over" occurs. Other races, however, have different combinations of these characters, such as white cobs and red seeds, etc., or red cobs and white seeds, or white cobs and striped seeds, etc., and these combinations hold together, when crossed to each other or to either of those first named. Here again each set of characters that go together may be caused by one factor or by a set of factors so closely linked that they do not separate (cross over). Now the striped seeds with white cob sometimes mutate to red seeds and red cobs. The combination acts as a unit toward the other known combinations. Therefore a single factor must have caused the change, for, if not, mutation must occur in two (or more) closely linked factors for seed and cob color at the same time, which is highly improbable.

Only two members of a series of multiple allelomorphs can be present in any one individual, and in the case of genes carried by the sex chromosome only one can exist at a time in the sex that has only one of these chromosomes. In the individual with two mutant allelomorphs one of them replaces the normal allelomorph of the ordinary Mendelian pair. The two mutant allelomorphs behave towards each other in the same way as does the normal and its mutant allelomorph. It is doubtful whether we can conclude from this relation much more in regard to the relation of Mendelian pairs than we knew before,[2] although there is at least a sentimental satisfaction in knowing that the normal allelomorph can be replaced by a mutant one without altering the working of the machinery.

[2] The substitution by crossing over really furnishes as good a demonstration of this point.

The linkage relation of each member of a series of multiple allelomorphs to all other genes of its chromosome is, of course, the same. While the theory of identical loci requires this as a primary condition it is not legitimate to use this evidence as a proof of the identity of the loci, because it is not possible to work with sufficient precision in locating genes by their relation to other linked genes to distinguish between identical loci and closely linked genes.

There is another question of some theoretical interest attached to the occurrence of multiple allelomorphs that calls for passing attention. If from the nature of the material mutation at a special locus were of such a kind that one step is essential before the next can be taken and if these genic steps give a progressive series of character changes, then it might appear to a person selecting for higher or lower grades of character in such a field that he was by his own efforts causing progress in the direction of his selection. In a certain sense he would be acting as an agent in hastening the possibility of the end result, because at each stage of progress he would breed as many individuals of the last stage reached as he could, and the number of individuals kept in stock would increase correspondingly the chance that some one of them would give the next mutant stage. Of course, the breeder here would be accelerating his end result not by controlling the conditions, so as to directly produce the change at will, but by making the chance that such an event would occur more probable by breeding a large number of individuals.

At present there is no evidence to show that multiple allelomorphic genes arise in the order of the development of the characters for which they stand. The few cases whose origin is known give exactly the opposite result. For instance, the octuple series of eye colors of *Drosophila,* grading from red to white, arose haphazard, so far as the amount of color shown by each mutant type is concerned. Mutation at this locus appears to take place more often than at any other locus, but not more often from the locus that has already mutated than from the wild type itself; in fact, more unit numbers of the series have appeared from the wild type, but this is expected if for no other reason than that more red-eyed flies pass under observation. It may be recalled in this connection that some other loci have been found that mutate to the same mutant type more often than do others, so that it may be that even some mutant loci may more frequently mutate than others or even than their own normal allelomorph. Since artificial selec-

tion is more likely to be followed up in cases where it is found to be giving results, it is not improbable that were such a condition realized it might easily mislead the breeder into supposing that his selection was producing progressive mutation changes, whereas he was succeeding because of a favorable situation that happened to fall into his hands.

While multiple allelomorphs present an extraordinarily interesting phenomenon of variation that has a profound bearing on our interpretation of the meaning of mutation, the facts indicate, so far as selection is concerned, that such allelomorphs fall into line with other mutants that supply selection with its material. The evidence shows in the most positive way that they originate as do other mutations, that the order of their appearance bears no fixed relation to the degree to which the character is displayed. Consequently they furnish selection with the same kind of material as all other mutations furnish. There is no evidence at present in favor of the view that selection has in itself any effect on the order of their appearance.

TECHNICAL PROBLEMS IN NATIONAL PARK DEVELOPMENT

By Professor FRANK A. WAUGH
MASSACHUSETTS AGRICULTURAL COLLEGE

OUR national park domain is already something quite unprecedented, something wholly glorious. The National Parks themselves comprise 17 splendid tracts amounting to 6,254,568 acres, including unique and unsurpassable features of landscape beauty. Nothing like this was ever brought under administration before, not even for the great military princes of the world; yet in this case we have a democratic reservation for the delight and the esthetic culture of all the people. Physically and ideally a new standard has been set in the world.

But in every proper sense our American national park system includes, not only the parks specifically so called, but other vast areas of land suitable for public recreation, and expressing in quite eloquent terms the great landscape forms of the North American continent. In other words, we must reckon in the wealth of our landscape equipment, in addition to the National Parks, also the 156 million acres of the National Forests; also some hundreds of thousands of acres of the National Monuments; while to these for many purposes we may further add the Indian reservations.

Still more: State parks and state forests have already been established in considerable numbers, and other important additions in this field may be expected in the coming years. These areas perform the same or a very similar service, and should be included in the general inventory.

In another paper I have tried to indicate some of the general policies which are likely to prevail in the development and administration of so magnificent a domain, but as we come nearer to the problem we see that it involves also a vast preparation of technical equipment, of specialized knowledge, of professional training for this peculiar work. The development and administration of a National Park must certainly prove to be as great and difficult a task as the training of a great symphony orchestra, the development of a modern service library, the making of a national art school, or the management of a state university. It seems self-evident that we shall need men

of large capacity, highly trained for this sort of work. While an enormous amount of specialized technical training will be necessary, it is still more important that such men shall have a broad foundation in the arts and sciences. They must be men of liberal culture in the best sense of that abused word.

In fact the very first technical problem in the development of our national park system lies in the training of a suitable personnel. To some extent a parallel is offered by the work of the National Forest Service. It must not be forgotten that at the time our National Forests were established on their present basis there came into useful activity a number of schools of forestry connected with our stronger universities. These schools gave a highly specialized training in technical forestry; but what was equally important, they inculcated sound ideals of public service. While the management of these National Forests has never been turned over to the graduates of the forest schools, these men have nevertheless exercised a far-reaching influence in that field. It is not too much to say that the genuine success of the Forest Service as a branch of federal administration, achieved in the face of great difficulties, has been due to the high ideals of the men of academic training combined with their thoroughgoing technical preparation.

It is not now necessary to discuss at any great length the character of the professional preparation required by the men who in the future are to administer our National Parks of all sorts. The training already provided for forest rangers and forest supervisors will be useful to many men engaged in park service, whether in national or state parks, or in forests used for recreation. The men who control general policies and administration are the ones who must have a broader training. The education given by the engineering and forestry schools will of course be valuable, but a broader outlook on general economics and sociology, with specialized applications in recreation, will have to be given considerable prominence. It seems to me further that special training in landscape engineering will be possibly most important of all. This, of course, does not refer to the popular idea of landscape gardening, concerning itself with the planting of "ornamental" shrubberies and pretty flower beds. The larger questions of structural design, however, have the utmost importance in their applications to the design and development of large park areas, even where that development consists mainly in letting alone the natural landscape. The well-trained park administrator unquestionably must have a highly developed sense of landscape values.

Lake Josephine, Mount Gould, Garden Wall, Grinnell Glacier.

Such a sense, logically developed and properly disciplined, can come from no other source, so far as I am able to see, except from a broad training in the principles of landscape engineering.

Determination of Boundaries

As the various parcels of our great park and forest domain one by one come under the administration of these trained men, other big technical problems emerge. The first of these is the determination of boundaries. Already it has been found that the great Yellowstone, the first of our National Parks, in spite of its liberal conception, fails to include such vitally important areas as Jackson's Hole, which now plainly ought to be a part of this park. We may expect that in a majority of cases a careful technical examination of the situation will show that boundaries of nearly all parks will need to be rectified. This will mean not only the acquisition of areas left outside, but also in many cases the recession of other areas originally included, but which on more careful examination can be shown to have more value for other uses. Any one who has had any experience in the study of parks, even on the small scale of the ordinary city park systems, has learned that this determination of boundaries is a highly delicate, difficult and technical matter, and one which requires long study.

Land Classification

Even before a final decision is reached regarding exterior boundaries, it will be necessary to classify the interior spaces for use. Certain areas will be needed for camping, some for summer colonies, some for playgrounds, some will be reserved for hunting and fishing, others will be game sanctuaries, some will be kept for the protection of natural curiosities, and so on through an almost endless list of special uses. To decide wisely what the needs of the public really are is a great and complicated problem, and one which from the nature of the case will never be ended. To apportion the land wisely to these various needs will require a knowledge of landscape values, of engineering methods, and of administrative problems of much more than amateurish degree. Even in the National Forests where these problems are much simpler, the land classification has occupied many years of study both broad and intensive. Certain it is that these problems of classification must be brought clearly before the men who are to be especially trained for park administration.

TRAIL IN A STATE FOREST.

TRAFFIC CIRCULATION

Park designers generally consider traffic circulation to be the one fundamental problem. It is beyond question of the utmost consequence. Parks are made for the delight of human beings, and human beings to enjoy the parks must circulate through them. The routes of circulation can be located in such a way as to reach all the scenes of greatest charm, or they can be so laid out as to miss all the best things and to present the visitor with a thoroughly mediocre picture of the entire park. At the Grand Canyon in Arizona, for example, a clear majority of the visitors get only one view of the Canyon, namely, that from the hotel El Tovar. The principal line of circulation lies westward nine miles along the Hermit Rim Drive, disclosing additional views of the Canyon below. Only a part of those who visit the Canyon go as far as this. A still smaller percentage take the Bright Angel Trail trip to the bottom of the Canyon, thus multiplying by ten-fold their knowledge of this unparalleled scenic wonder. A very much smaller percentage of Grand Canyon visitors cover what is known as the Tonto Loop, including the beautiful Hermit Creek Trail. While this round trip of 25 or 30 miles is far beyond the experience of

the ordinary Canyon visitor, it still reveals hardly more than a minor fraction of the Canyon glories. Miles and miles of trail will be necessary eventually to lead visitors into all parts of the Canyon, and to give them anything like an adequate experience of the place. The study of such a system of circulation is an engineering problem of the highest order, but a problem which requires a combination of engineering skill with a knowledge of landscape values.

Trail Design and Construction

A general plan of traffic circulation once determined, it becomes necessary to locate and construct the trails in detail. These may be automobile roads, carriage drives, mule trails or foot paths. The general principles of design involved are the same in either case. I have tried to state this problem and to outline the technical methods of its solution in my recent book on "The Natural Style in Landscape Gardening." At the present time it may be sufficient to point out that the artistic method involves the same procedure as prose composition. A definite landscape theme is adopted, and this theme is exclusively presented along a considerable section of trail. As in prose, so in landscape engineering, the theme is developed by paragraphs. The whole length of the trail is divided into sections, and each one of these presents some definite aspect of the theme in hand. Such paragraphs must have a logical se-

Typical Forest, Yellow Pine Country. This particular section has been set aside for purposes of recreation.

quence. There must be a definite statement of the theme in the first paragraph, there must be a varying treatment in successive paragraphs, running from grave to gay, from coquettish glimpses to broad expository views, and leading to something like a climax toward the end.

We are here in touch with the more technical problems of landscape engineering, but we are dealing with matters which plainly may have a very wide and useful application in the development of those great areas of natural landscape which constitute our National Parks and National Forests.

General Construction

All kinds of playgrounds, camps, summer colonies, etc., will have to be laid out on various park and forest areas, and their

Grand Canyon of the Colorado, from Hermit River Road, Arizona.

location and design also involve intricate technical problems. A camp has to be protected in sanitary ways; a water supply has to be provided which is beyond the suspicion of contamination; some adjustment has to be made relative to several kinds of public service. These are largely the questions which come up in city planning and civic design generally. They are pretty well understood; and especially in the schools of landscape architecture men have already been trained for such work. In

the National Parks and Forests we shall fitly have a new application of the old principles. The problems will be infinitely varied and infinitely interesting.

MAINTENANCE

Park superintendents experienced in the management of city park systems have learned to distinguish clearly between park design, construction and maintenance, and to organize their labors accordingly. Park maintenance indeed has come to be a sort of profession by itself. The importance and the intensive character of this work may be surmised from the fact that the average cost of city park maintenance throughout the country is well over $100 an acre a year. On our millions of acres of national park and forest lands a much lower rate of maintenance will be adopted, necessarily and properly; but the complex and highly technical quality of the problems involved will appear none the less. Such questions as the cost of lawn mowing, the application of dust layers on roads, the transplanting of trees, the breeding of wild-fowl, the protection of fish, the use of preservative solutions on fence posts, the policing of camps, guarding against fires, the operation of telephone lines, keeping ice clean for skating, and a thousand other practical matters will require attention. In this field thorough training and practical experience must be added to considerable natural aptitude to produce a park officer of high efficiency.

It is all of a piece with our greatest American problem, how to secure real efficiency in our public service while at the same time avoiding the deadly blight of bureaucracy. Everywhere we need trained men. We need to get away from the tempting idea that any free-born American can ex-officio do anything. We have taken a good many things out of the hands of grafting politicians and turned them over to willing amateurs, thereby gaining much. If now we can make the next move and place our public business in the hands of men highly trained in technical ways (always with high ideals of public service) we shall be gaining even more. In the park service which is to be we may realize these noble possibilities relatively soon, since the need is so obvious and the way so plain.

A Lecture on Anatomy. From the Italian translation of "Ketham," Venice, 1493.

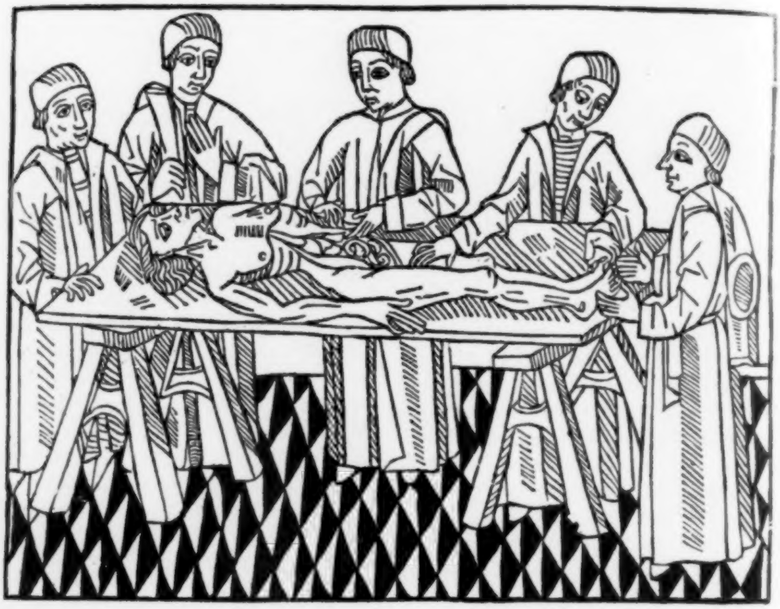
THE PROGRESS OF SCIENCE

THE BEGINNINGS OF ANATOMICAL DISSECTION

THERE has been published by the Oxford University Press a scholarly volume, entitled "Studies in the History and Methods of Science," edited by Charles Singer, who contributes two of the seven articles. Sir William Osler has prepared an introduction in which he states that it was hoped to establish a journal on the history and methods of science and to organize a summer school for special students at Oxford. Owing to the war the plans have been abandoned, or at least postponed, and certain of the studies are now printed in this volume. Through a gift of Dr. and Mrs. Singer an alcove in the Bodleian Library has been fitted up with a collection of books and manuscripts to enable the general student to acquire a knowledge of the development of science and to assist special students in their researches.

One of the studies is an account of early Renaissance anatomy by the editor of the volume. It contains a number of illustrations of dissections, several of which are here reproduced. The dissection of the human body, first practised by the Alexandrian school, was revived by Mondino, who was professor at Bologna in the early part of the fourteenth century. The illustration here reproduced is from a volume containing a treatise by Mondino and other medical tracts, printed at Venice in 1493. The plate is of interest, both in relation to the history of anatomy and to the art of printing. It is said to be the best

THE EARLIEST KNOWN REPRESENTATION OF THE PRACTISE OF DISSECTION. From an MS. in the Ashmolean Museum, Oxford, of about 1298.



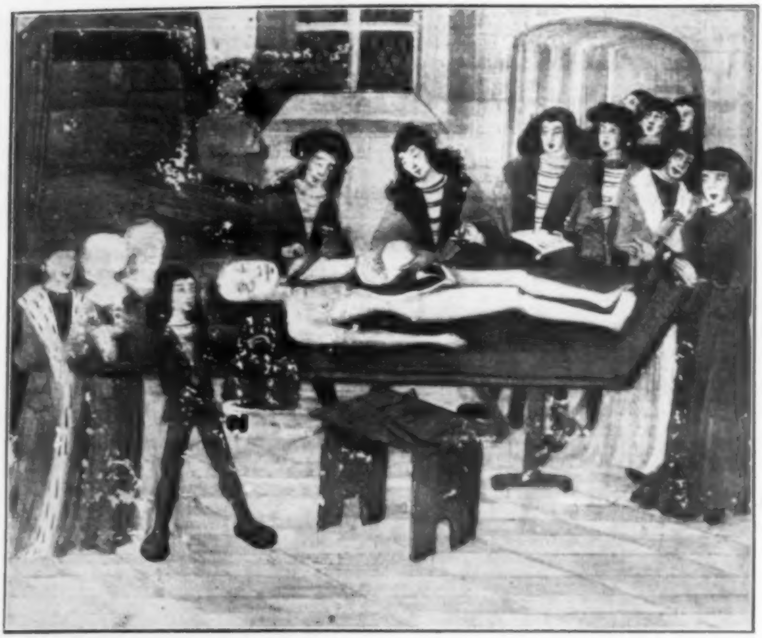
THE FIRST PRINTED PICTURE OF DISSECTION. From the French translation of Bartholomaeus Anglicus, Lyons, 1482.

example of book illustration produced during the first century of typography, and it was the first attempt at a complete color scheme, four pigments being laid on by the use of stencils.

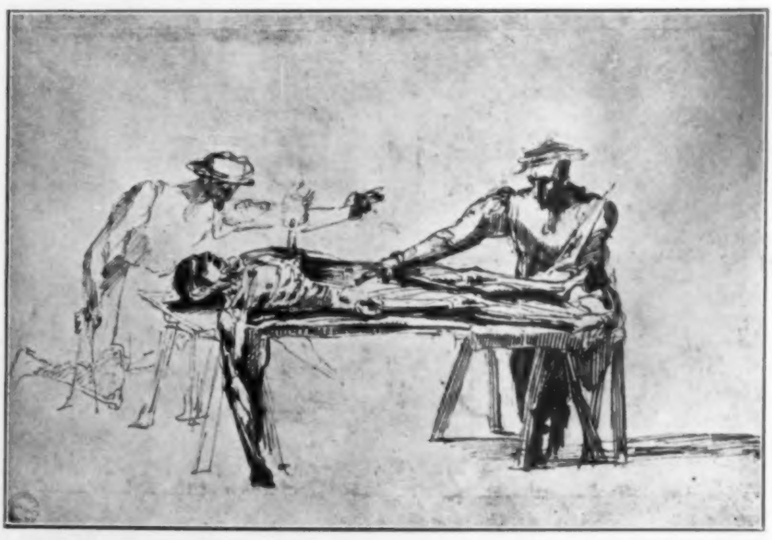
The illustration shows the method of teaching anatomy at that time. The professor, perhaps intended to represent Mondino, is portrayed standing at a desk, well removed from the subject of dissection. He reads from a manuscript or book a description of the parts dissected by the assistant. The professor of surgery may stand by with a pointer to indicate the different organs. At Bologna it was arranged that each medical student of over two years standing should attend a dissection or "anatomy" once a year, twenty students being permitted to see the dissection when the subject was a man and thirty for a woman. Men were used more frequently than women, owing to the fact that only the bodies of criminals were used, and there were more male than female criminals. This was all the practical instruction a student received, and in some universities there was only a single dissection each year for the whole body of students.

The lecturer was likely to depend more on Galen or on some other authority whom he read than on the facts disclosed, so that while dissection was usual in medieval universities, there was but little progress in anatomical knowledge until the time of Vesalius, born in 1514.

The earliest known representation of the practise of dissection, reproduced by Dr. Singer from a manuscript in the Ashmolean Museum, Oxford, is of the date of about 1298 and thus precedes the first dissections of Moldino at Bologna. A post-mortem examination is apparently being conducted surreptitiously, but the illustration from a



A Post-mortem Examination. From a manuscript in the library of the Montpellier School of Medicine, late fourteenth century.



Two Figures Dissecting, traditionally said to represent Michelangelo and Antonio della Torre. From a drawing in the Ashmolean Museum, Oxford, attributed to Bartolomeo Manfredi (1574(?)-1602).

French manuscript of the fourteenth century shows a post-mortem examination conducted openly in the presence of the relatives of the deceased. The physician in full canonicals is at the extreme right. The actual process of examination is being made by three of his assistants. To the left, the first of these deepens, with a knife, the incision that has already been made over the sternum, the second is grasping with his two hands and rolling up the great omentum so as to display the viscera beneath, and the third holds the wand in his right hand, with which he points to the abdomen, while in his left he carries a book.

The artist who went direct to nature, dissecting with his own hands and observing with his own eyes, obtained better results than the professor with his formal methods. Leonardo da Vinci made admirable anatomical sketches. Michel Angelo is said to be one of the two figures shown in the last illustration, which dates from the end of the fifteenth century.

SULPHURIC ACID AND THE WAR

THE British government is having the foresight to consider problems that will arise after the war and has appointed a departmental committee to report on the post-war disposition of the sulphuric acid and fertilizer trades. Professor T. L. Thorpe

THE FIRST PICTURE OF DISSECTION IN AN ENGLISH-PRINTED BOOK. From the English translation of Bartholomaeus Anglicus, printed by Wynkyn de Worde, 1495.

gives in *Nature* an account of the report of the committee, which is of interest in this country as well as in England.

Sulphuric acid is indispensable for warfare and the enormous amount needed in the manufacture of explosives and for other purposes has led to an extraordinary development of the industry in England. Concentrating plants on a large scale have been everywhere erected, and the productive power of the country has reached an amount greatly in excess of the pre-war consumption. The problem of the committee is how this extension can be dealt with in view of the requirements when the war is ended.

According to Professor Thorpe there is one new source of sulphuric acid in England, created by the war, which should be maintained and extended, and that is the production of acid from Australian zinc concentrates. The manufacture of zinc was instituted in England before it was started in Belgium and Germany, but it has not been developed there to the same extent. Although London is the chief zinc market in Europe, the main production of the metal has been in the hands of Germans, who have also acquired a controlling interest in the Belgian concerns. It is said that Germany, with the view of maintaining her practical monopoly in the production and distribution of zinc, gained control of the rich deposits of zinc ores in Australia, and that the great bulk of the Australian concentrates found their way to Belgium and Silesia, mainly by way of Antwerp and Hamburg, Germany's own deposits being meanwhile conserved.

There is one outlet for sulphuric acid which is capable of far greater development, and that is in the manufacture of fertilizers, and especially of superphosphates. There can be no doubt that the food shortage in England has had a profound effect on agricultural policy, and will lead to a permanent increase in home production. This will necessitate a greatly increased demand for fertilizers, such as sulphate of ammonia, as well as of phosphatic manures. Much ammonia is at present absorbed in the production of nitrate of ammonia, which is needed in the manufacture of munitions. But this ammonia will be liberated after the war, and will be largely converted into sulphate for agricultural use. In the past about 60 per cent. of the sulphuric acid produced in England was absorbed in the manufacture of fertilizers, in which there was a considerable export trade, in addition to the home demands. The changed carrying conditions caused by the war may, it is said, lead to an extension of this export trade, induced, on one hand, by the comparative abundance of cheap sulphuric acid, and, on the other, by the greatly increased demand for fertilizers.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE annual meeting of the American Association for the Advancement of Science and of the national scientific societies affiliated with it will be held at Baltimore, from December 27 to December 31. Boston had been selected as the place of meeting this year, action recommending that the meeting be held in that city having been taken at the meeting in New York City two years ago. In view, however, of war conditions and of the large number of scientific men now working at Washington, it seemed desirable to select a place to which the amount of traveling would be reduced as much as possible, and where a meeting concerned with problems of national defense and national welfare

could be held to best advantage. The situation was carefully considered at the meeting of the committee on policy held in Washington on April 22, and it was decided that it would be desirable to meet in Baltimore. President Goodnow and the professors of the scientific departments of the Johns Hopkins University having cordially welcomed the plan, it has been definitely decided that the meeting will be held in that city. A committee consisting of Dr. L. O Howard, the permanent secretary, Dr. W. J. Humphreys and Professor J. C. Merriam has been appointed to report on a general plan for a program that will make the meeting of the greatest possible service to the nation.

The committee on grants of the American Association has made the following appropriations:

$300, to Mr. William Tyler Olcott, secretary, American Association of Variable Star Observers, 62 Church Street, Norwich, Connecticut, for the purchase of a telescope of 5-inch aperture.

$250, to Professor A. E. Douglass, of the University of Arizona, Tucson, Arizona, for the length of record of tree growth of the Sequoias from about 2,200 to 3,000 years.

$500, to Professor Carl H. Eigenmann, of Indiana University, Bloomington, Indiana, for the study of the fresh-water fishes of South America.

$500, to Professor Edwin B. Frost, of Yerkes Observatory, Williams Bay, Wisconsin, for measurement and reduction of photographs of stellar spectra, already taken with the 40-inch telescope.

$200, to Dr. R. A. Porter, of the University of Syracuse, Syracuse, New York, for explanation of the hysteresis which has been observed in the potential gradients of the calcium-cathode vacuum tube.

$200, to Professor E. W. Sinnott, of The Connecticut Agricultural College, Storrs, Connecticut, for experiments to determine the ratio (in dry weight) between root, stem, leaf and fruit in the bean plant.

$500, to Professor O. F. Stafford, of the University of Oregon, Eugene, Oregon, for research on the distillation of wood.

$200, to Professor Herman L. Fairchild, University of Rochester, Rochester, New York, for the continuation and completion of his studies on the Post-Glacial continental uplift in New England and the Maritime provinces of Canada.

$250, to Professor S. D. Townley, secretary, Seismological Society of America, Stanford University, California, for the investigation of earthquake phenomena.

SCIENTIFIC ITEMS

We record with regret the death of Ewald Hering, the eminent physiologist, professor at Leipzig; of Dr. Ferdinand Braun, the German physicist who shared the Nobel Prize in 1905 with Guglielmo Marconi, for work in wireless telegraphy; of H. J. Helm, chemist of the British Government Laboratory, and of G. Meslin, director of the physical laboratory of the University of Montpellier.

Director William Wallace Campbell, of the Lick Observatory, University of California, has been elected a foreign member of the Royal Society.—The Geological Society of France has awarded to Dr. Henry Fairfield Osborn, president of the American Museum of Natural History, the Gaudry Medal, which was established by the society in the wear 1910 in honor of the distinguished French paleontologist, Albert Gaudry.—The Boston Society of Natural History has awarded the Walker Grand Honorary Prize, in the shape of a one-thousand-dollar Liberty bond, to Professor Jacques Loeb, of the Rockefeller Institute, New York, in recognition of his many published works covering a wide range of inquiry into the basic concepts of natural history.

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